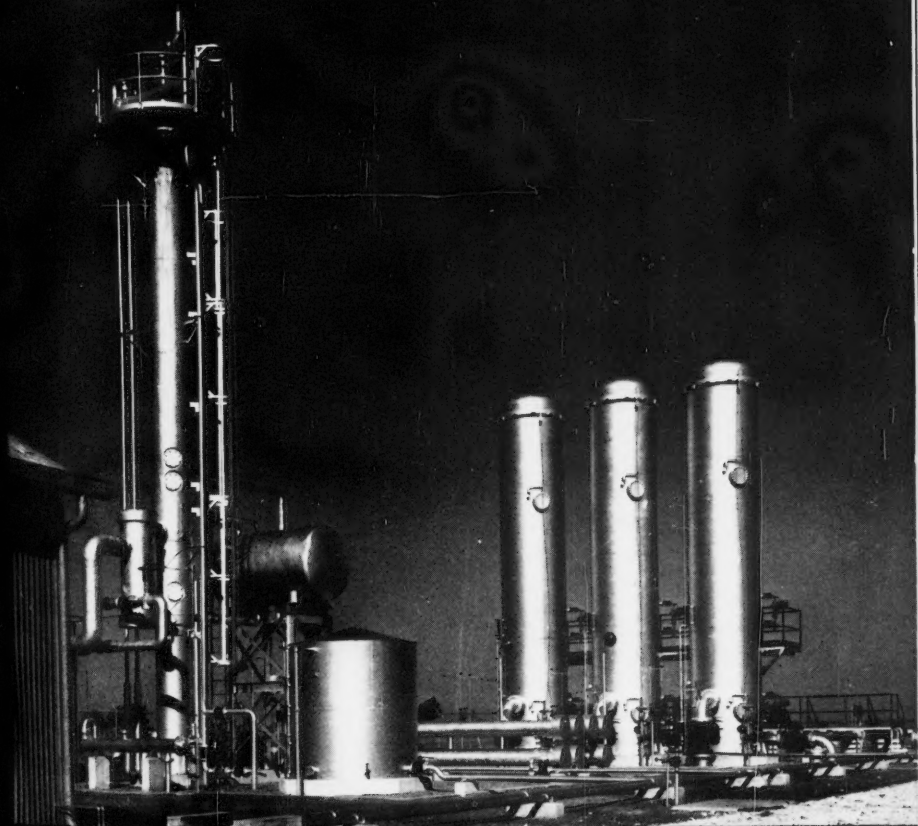


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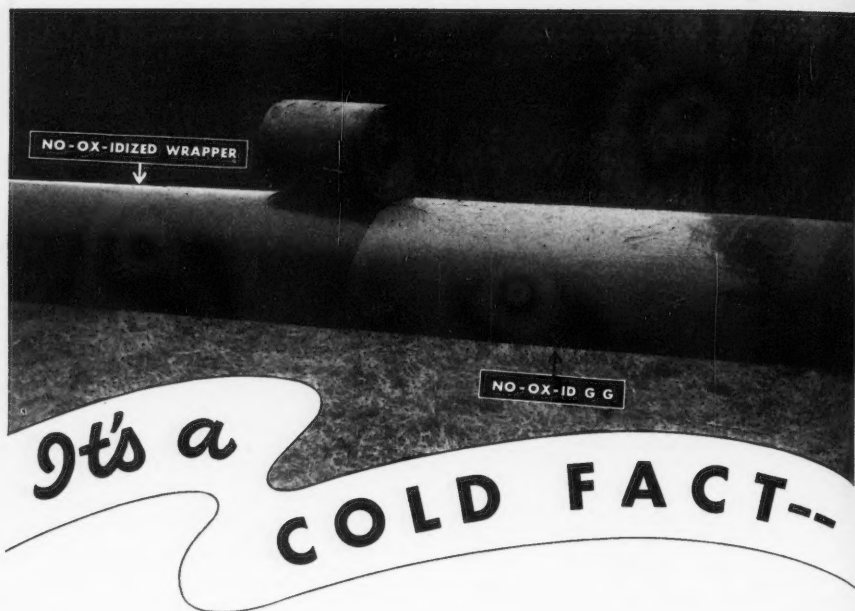
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Vol. 4

November, 1948

No. 11



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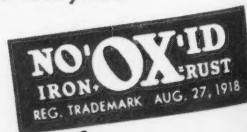
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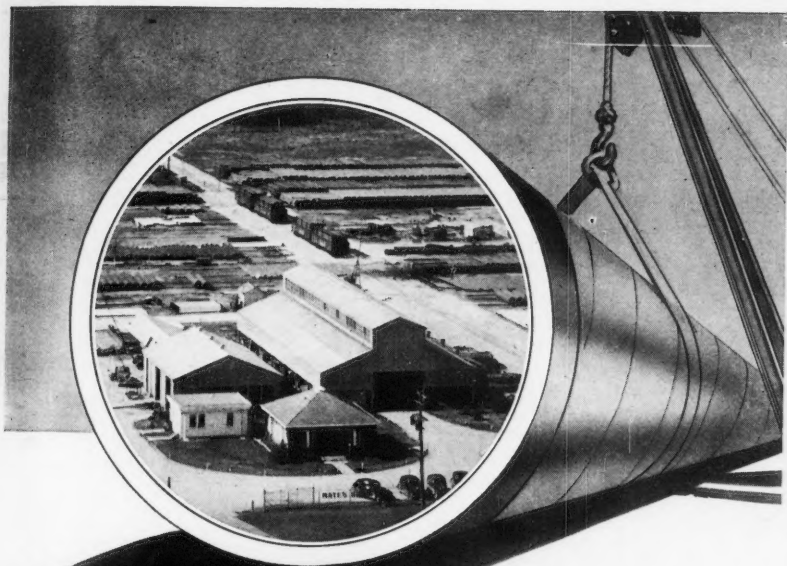


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Corrosion

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CONTENTS

A Simple Test Method for Evaluating Corrosion Inhibitors By J. W. Ryznar and J. Greene	505
Corrosion Problems in the Manufacture of Soda Ash by the Ammonia Soda Process By Gustave Heinemann	516
Corrosion of Underground Power Cable Sheaths By L. F. Greve	529
Some European Researches on Passivity By U. R. Evans	545
Plastic Coatings and Corrosion By C. G. Munger	557
A Message From Your Officers	xi
Topic of the Month	566
NACE News	2
Corrosion Abstracts	17
Index to Advertisers	52

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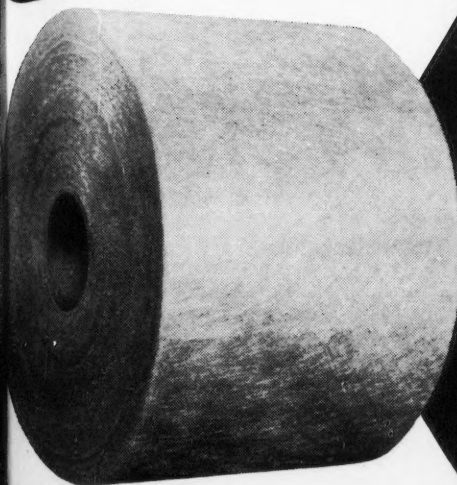
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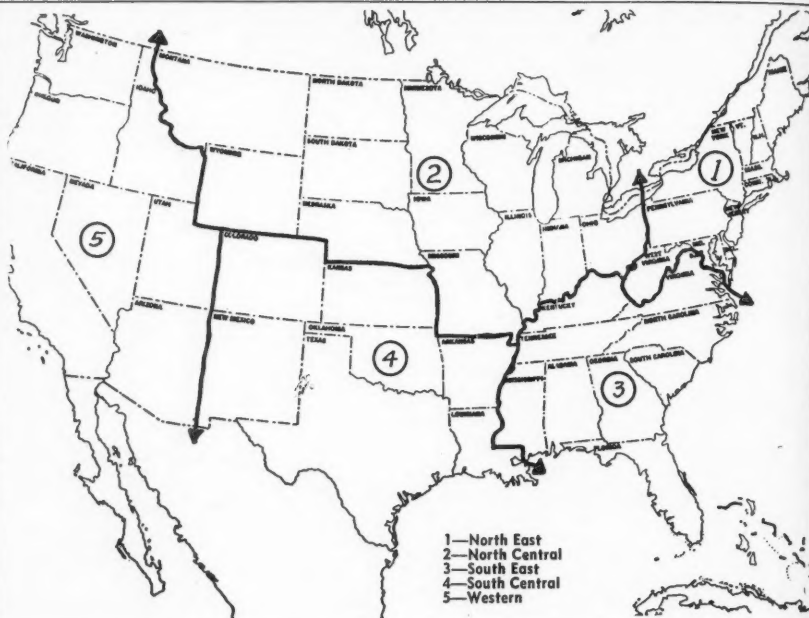
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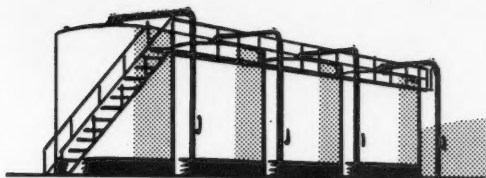
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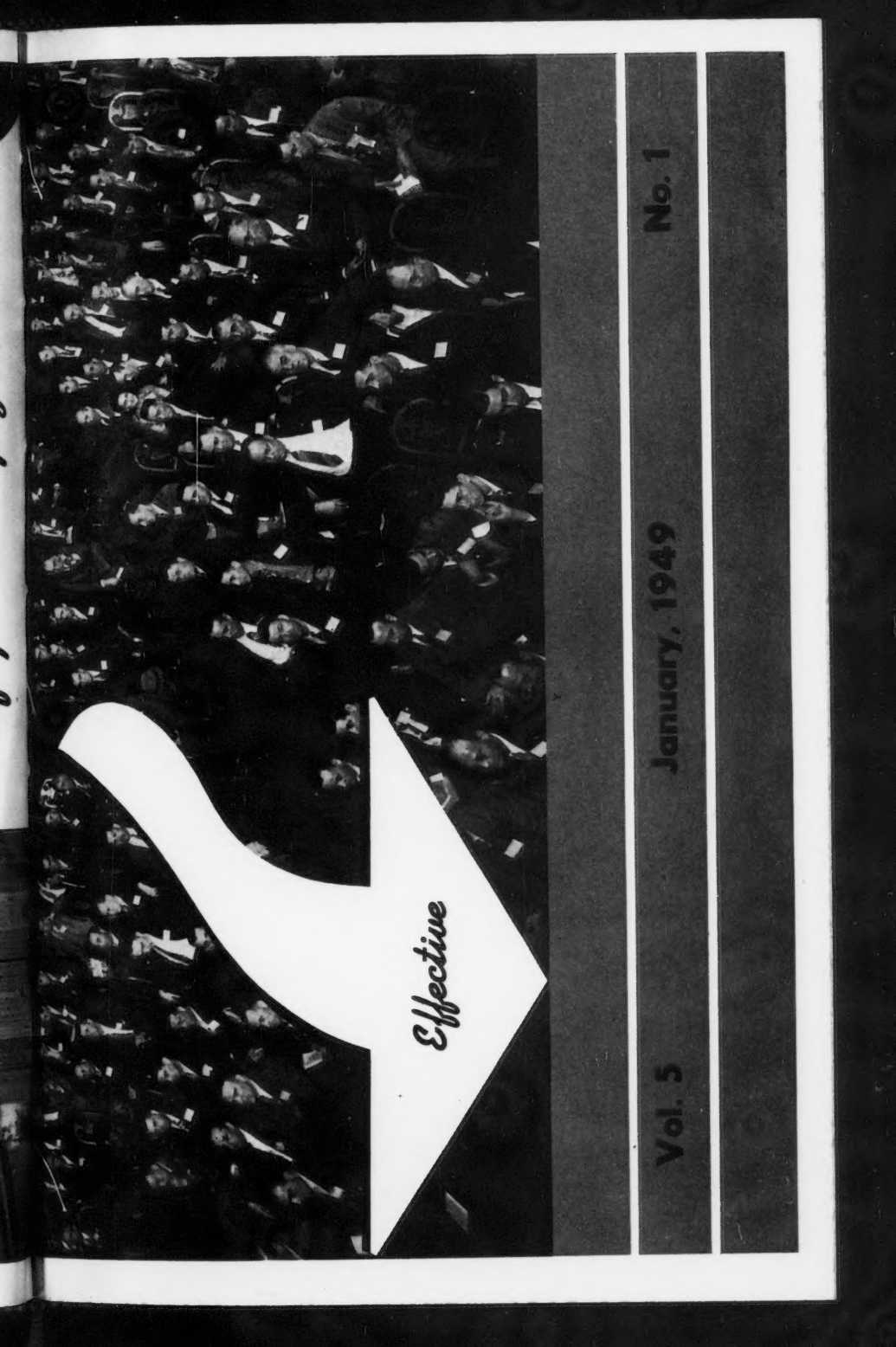
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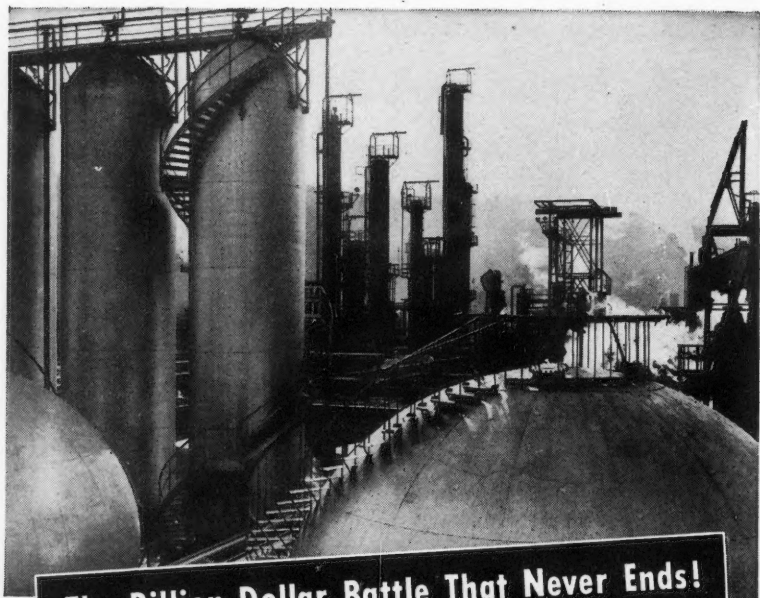


Effective

Vol. 5

January, 1949

No. 1



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A Message from Your Officers

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IN 1935 a group of corrosion engineers banded themselves together into a loosely knit organization with the avowed object of improving cooperation and fostering the exchange of information to the end that all would be better equipped to combat their common enemy, corrosion. Through devious channels this group finally emerged as the nucleus of what we now know as the National Association of Corrosion Engineers.

In broad terms, the aims or purposes of the National Association of Corrosion Engineers are still the same as those expressed by this original group in 1935. Certainly these objects are broad enough to support a badly needed structure of service to the industry and to the membership.

For the past several years the efforts of the NACE organization have been expended primarily upon the organization and consolidation of the group as a national body, and that the progress which has been achieved is considerable cannot be denied. The expansion of the Association has been, and is, rapid and healthy, and there can be little doubt but that continued effort along the present lines will eventually result in a national organization of tremendous importance to the industry, as well as its individual members.

One of the primary hopes of the original founding group was that the Association would one day find itself in a position to assume leadership in the prosecution of investigation, research and development on problems pertaining to some of the basic causes of corrosion and corrective techniques, the solution of which may require intensive study by individuals and groups particularly qualified to handle these individual problems.

The organizational structure of NACE is now reasonably well established, and there are definite indications that the financial structure is reaching a point at which consideration may be given to providing space in the budget for financing the study of certain problems and for the organization of supervised committee work. Certainly it is not too soon to be giving thought toward this end. Whether this work should be financed by fellowships, by outright grants from industry, or by some other means is a detail which can be worked out once definite plans are set up for the NACE organization to supervise these studies.

It is true that the work of such committees as have been appointed has been very worthwhile, but it is equally true that the efforts of these committees were definitely handicapped by the lack of proper organization and supervision within the structure of NACE; and it is this organization and engineering direction which needs immediate study, as it must be provided if we intend to maintain the prestige we now enjoy as the National Association of Corrosion Engineers.

THE NATIONAL ASSOCIATION OF CORROSION ENGINEERS

is a non-profit, scientific and research association of individuals and companies concerned with corrosion or interested in it, whose objects are:

(a) to promote scientific research in determining the causes of corrosion and methods of its control with respect to theory and practice.

(b) to provide a means of exchange of knowledge and ideas among those individuals actively engaged in the control of corrosion.

(c) to promote methods of control of corrosion.

(d) to promote standardization of terminology, methods, equipment and design in the development of methods of corrosion control.

(e) to foster cooperation between individual owners of metallic structures in the solution of their joint corrosion problems.

It is an incorporated association without capital stock, chartered under the laws of Texas. Its affairs are governed by a Board of Directors, elected by the general membership. Officers are nominated by (1) the Board of Directors, or (2) a quorum of at least 25 members, and elected by the membership.

Inquiries regarding membership, and all general correspondence should be directed to the Executive Secretary at the administrative headquarters of the National Association of Corrosion Engineers at 905 Southern Standard Building, 711 Main Street, Houston 2, Texas.



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A Simple Test Method for Evaluating Corrosion Inhibitors*

By J. W. Ryznar* and J. Greene*

Introduction

ONE METHOD of corrosion prevention by water treatment involves the use of chemicals, which in relatively small amounts greatly reduce or inhibit attack. There is little information concerning the exact mechanism by which such materials or inhibitors function; consequently, there is often no sound basis on which to select the most effective inhibitor or the concentration of inhibitor for a particular set of conditions. For the same reason, the possibility is open that materials other than the known inhibitors may have corrosion preventive properties or may enhance the effectiveness of proved inhibitors when used in conjunction with them.

In developing inhibitor treatments which may be generally applied the situation is further complicated by the wide variety of waters which may be encountered in practice. The net result of these factors is that a relatively large number of tests must be carried out in order to obtain the information desired. Hence, there is a need for a simple, rapid, reliable laboratory test for screening possible corrosion inhibitors and

for evaluating those materials which are found to be effective. It is the purpose of this paper to describe such a test which has been successfully used for a number of years.

Laboratory Test

The requirements of a valid laboratory corrosion test are severe. No single test is capable of application to all of the wide variety of corrosion problems encountered in practice. The general requirements which are common to all tests, however, are the control of those variables which influence corrosion. With respect to environment, the most important of these variables are temperature, dissolved oxygen, velocity of water relative to the metal, pH, electrolytes, and naturally occurring or added inhibitors. The extent to which these factors are taken into account are made evident in the description of the laboratory test which follows and from the results obtained.

The main purposes of the test are 1) to determine whether a substance will or will not inhibit corrosion sufficiently to be of practical importance, 2) to determine significant differences in the effectiveness of inhibitors or between different concentrations of the same inhibitor,

* A paper presented at the Annual Meeting of NACE in St. Louis, Mo., April 5-8, 1948.

* National Aluminate Corp., Chicago, Ill.

and 3) to determine the effectiveness of a given inhibitor under a variety of environmental conditions.

A drawing of the apparatus is shown in Figure 1. A solid cylinder of metal, A, is rotated at constant speed by means of a motor, B, for 24 hours in a water containing the inhibitor to be tested. Visual examination of the specimen at the conclusion of the test is the main criterion used to evaluate the results. Supplementary information is obtained from the measurement of the potential of the metal with respect to the water and from the analysis of the water for iron.

A solid cylindrical specimen approximately 0.25 inch in diameter and approximately three inches long is prepared from quarter-inch round hot rolled SAE 1020 mild steel. Filing and abrasion with No. 1/0 emery cloth are used to produce a uniformly smooth but not highly polished surface. Prior to immersion of the specimen, it is again polished with No. 1/0 emery cloth and wiped with a clean piece of filter paper. This final polishing is done while the specimen is mounted and rotating. The elapsed time between this final polishing and immersion is only a matter of a few seconds.

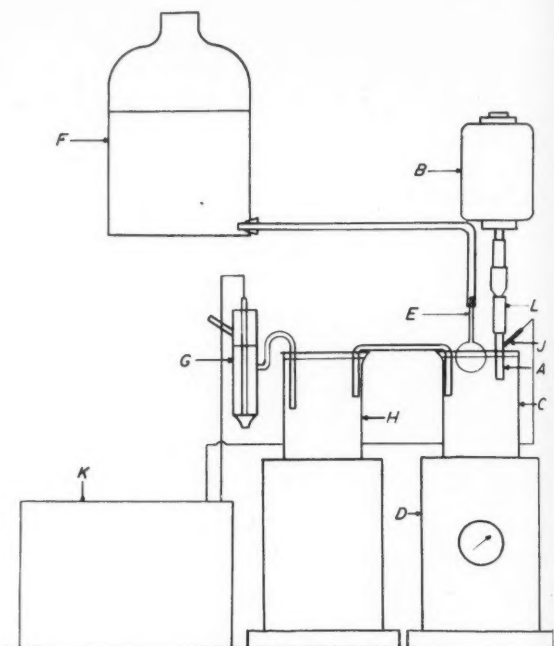


Figure 1—Schematic of Test Apparatus.

The cylindrical form of the specimen provides a favorable ratio of area to edge. The edge is rounded off slightly and in tests conducted at room temperature a thin coating of paraffin is applied to it and to the bottom of the specimen. A narrow band of paraffin is also applied to the periphery at the water line, which is located one inch from the bottom of the specimen. The area of the exposed metal for these conditions is approximately 0.75 square inch. In tests conducted at higher temperatures, no paraffin coatings are applied. In these cases the area of the exposed surface is approximately 0.80 square inch.

Analysis of Water Used in Test

The water used in routine tests consists of Chicago tap water and distilled water in equal volumes to which sodium chloride is added to increase its concentration by 10 grains per gallon. The analysis of this composite water follows:

Ca.	2.3
grains/gal. expressed as CaCO_3	
Mg.	1.5
grains/gal. expressed as CaCO_3	
Alk. to methyl orange. . .	3.3
grains/gal. expressed as CaCO_3	
NaCl	11.4
grains/gal. expressed as NaCl	
Na_2SO_4	0.6
grains/gal. expressed as Na_2SO_4	
SiO_2	0.07
grains/gal. expressed as SiO_2	
pH	7.0

This water is fairly representative of corrosive ones which are commonly encountered. Other compositions of water, as well as specimens, can be used, of course, to provide a closer approximation to the conditions which prevail for a particular corrosion problem. The volume of water used is approximately 600 ml. This provides a ratio of volume of water to area of specimen considerably greater than the minimum of 8.6 recommended by Calcott, Whetzel, and Whittaker.¹

The test water is contained in a Pyrex beaker, C, which is supported on an electric heater, D. The temperature is maintained within a few degrees of the desired value by the adjustment of rheostats on the heater. The volume of water is kept constant by a float valve arrangement, E, which automatically maintains the original water level through

the admission of distilled water from a reservoir, F.

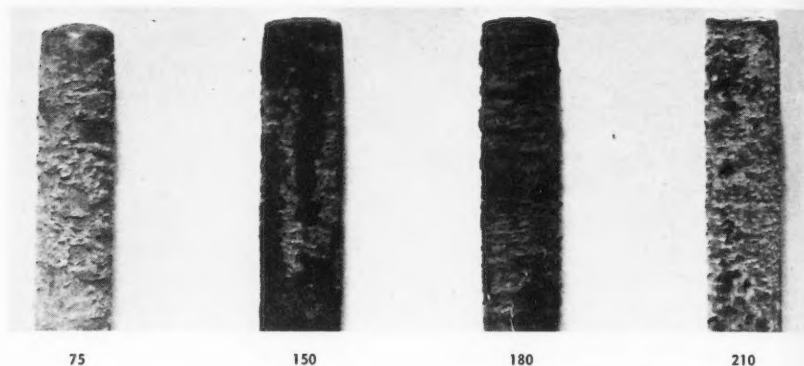
The potential of the specimen is measured relative to a one-normal calomel half-cell, G. In tests conducted above room temperature, junction between the test water and the calomel cell is made through an intermediate beaker of test water, H, at room temperature. A strip of brass, J, makes a sliding electrical contact with the rotating specimen. Potential differences are measured by means of a slide wire potentiometer, K.

In carrying out a test, the specimen is inserted in an insulated holder, L, and mounted in the chuck of the motor. It is then immersed to a depth of one inch in the water and rotated at constant speed for 24 hours, during which time potential measurements are made at suitable intervals.

After the specimen has been dried, the results are evaluated on the basis of visual observations. Considerable emphasis is placed on evidence of local corrosion.

Recently, the development of a scoring system similar to that of Darrin² has been initiated. At the conclusion of a test the water is analyzed for iron by a colorimetric method. This measurement and the potential data are used to supplement the information obtained from the visual inspection of the specimen.

Axially rotating cylindrical specimens have been used by others in corrosion testing,^{3,4} but it is believed that the application of this feature to the study of corrosion inhibitors and the measurement of potentials under such conditions represent in-



Temperature—Degrees Fahrenheit. Velocity 1.9 Ft./Sec. Standard Water.

Figure 2—Effect of Temperature.

novations. The effects of the more important environmental variables on corrosion are too well known to require elaboration here. That the test which has been described is capable of demonstrating these effects is shown in the accompanying illustrations.

The effect of temperature on corrosion is shown in Figure 2. The increase of rate of reaction and diffusion with temperature predominates at first. As the temperature increases its effect on the concentration of dissolved oxygen in an open system becomes more important, finally resulting in considerably reduced corrosion near the boiling point of water.

The influence of dissolved oxygen on corrosion depends on its concentration and on the rate at which it reaches the metal surface. Emphasis in the testing method described is placed primarily on conditions where little or no corrosion occurs. Under such conditions experiments have shown that substantially complete air-saturation of the

water is obtained, obviating the necessity of bubbling air through the water.

The rate at which oxygen is brought to the metal surface is primarily dependent on the velocity of the water relative to the metal. Under some conditions corrosion may decrease when the velocity reaches a certain high value, because the supply of oxygen to the metal surface has become great enough to cause the formation of a protective film of iron oxide. This effect, which has been demonstrated by other observers, is shown in Figure 3. An increase in velocity also increases the rate at which other constituents in the water reach the metal surface. Hence, when appreciable concentrations of deleterious substances are present the formation of a protective film due to oxygen alone is usually not possible.

The relative motion between water and specimen is of particular importance in tests involving corrosion inhibitors because it deter-

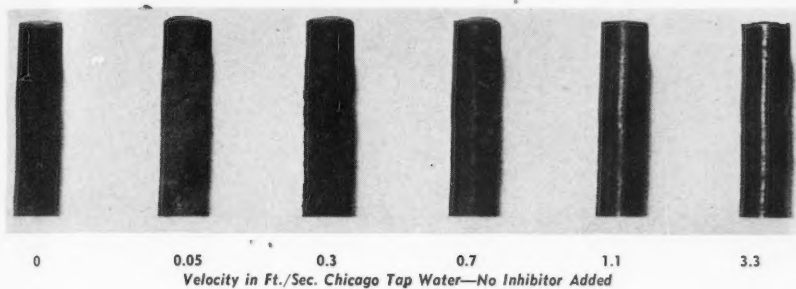


Figure 3—Effect of Velocity.

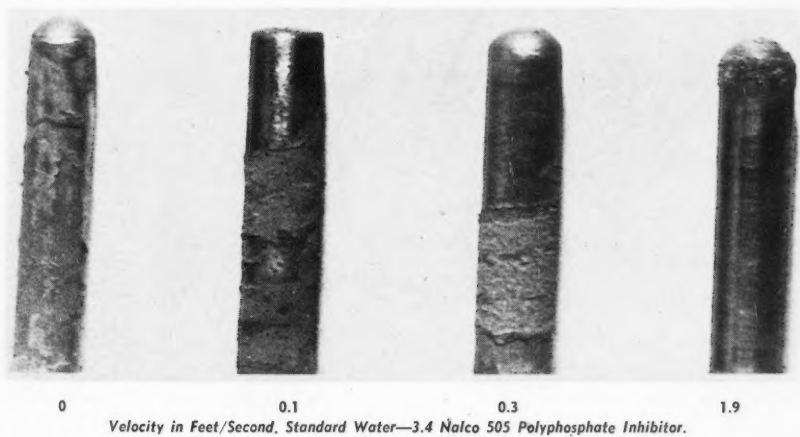


Figure 4—Effect of Velocity.

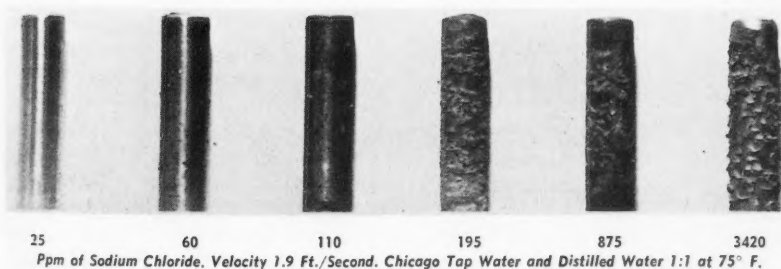


Figure 5—Effect of Sodium Chloride.

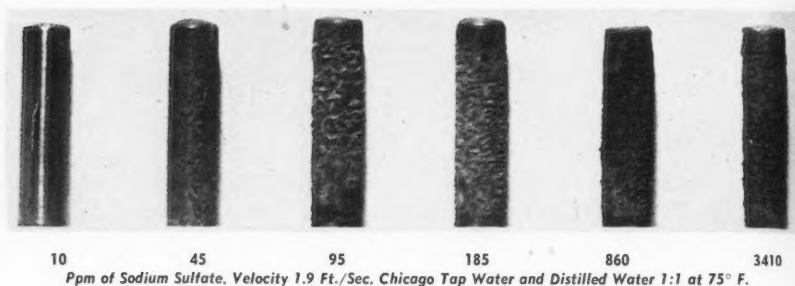


Figure 6—Effect of Sodium Sulfate.

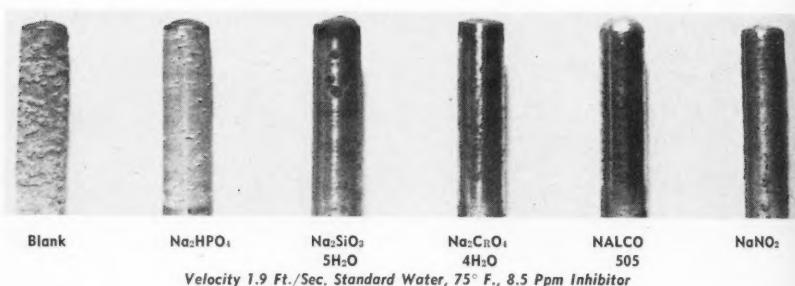


Figure 7—Results with Various Inhibitors.

mines to a large extent the rate at which inhibitor is brought to the metal surface. This factor is illustrated in Figure 4. The velocities are in the range where the corrosion rate is still high in the absence of inhibitors. In routine tests, largely for convenience, a motor speed of 1750 rpm is used, corresponding to a peripheral velocity at the surface of the specimen of 1.9 feet per second.

While no provision is made for the control of pH, experience has shown that in the absence of appreciable corrosion changes in this variable are not large provided the initial pH is not far from neutrality. The buffering capacity of the water

contributes to stability in this respect. If control of pH is desired it is usually possible to accomplish this by the addition of acid or alkali at suitable intervals.

The marked effects of certain electrolytes on corrosion are illustrated by Figures 5 and 6, which show the deleterious influence of chloride and sulfate ions. The increase in corrosion rate by such ions has been ascribed to the increase in conductivity of the water and the breakdown of the iron oxide film. On the other hand, ions which form relatively insoluble compounds with iron usually reduce corrosion. This is believed to be the basis for the effectiveness of certain of the known

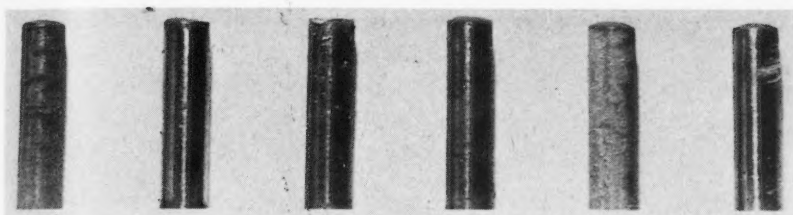
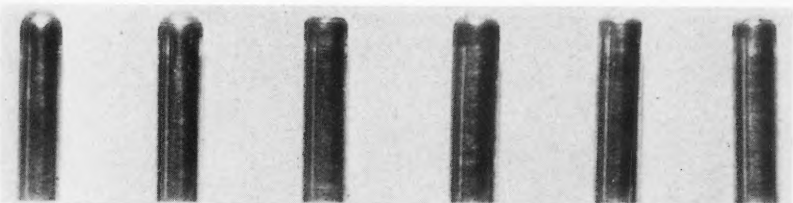
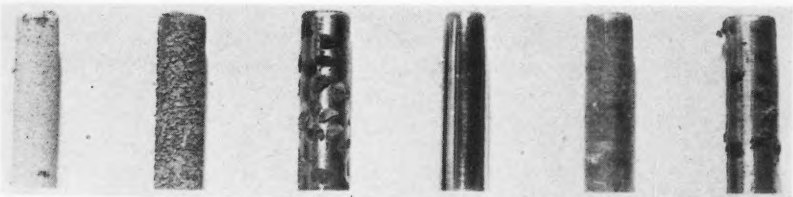


Figure 8—Variation of Inhibitor Concentration Required for Different Waters.



Velocity 1.9 Ft./Sec. Standard Water at 75° F. 6.8 Ppm Nalco Polyphosphate Inhibitor.



anodic inhibitors of ferrous corrosion. Illustrations of the influence of a number of these materials is shown in Figure 7.

For a particular set of conditions there is usually a minimum concentration of a given inhibitor required for complete protection. This

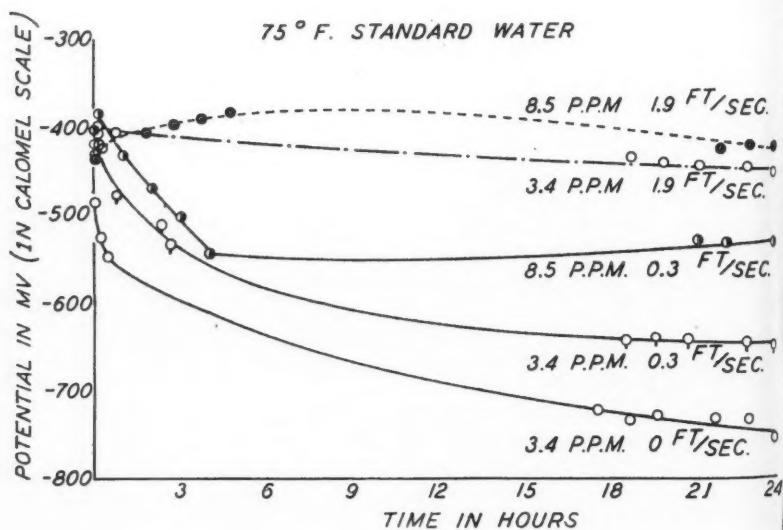
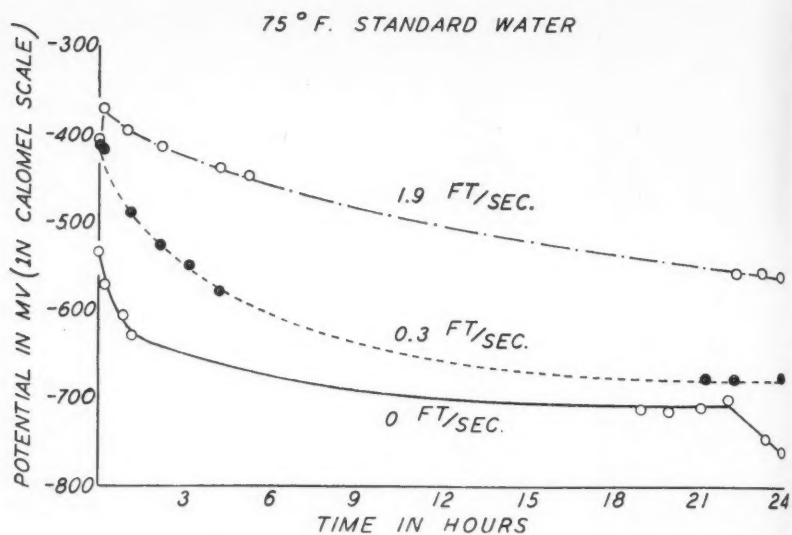


FIGURE 11

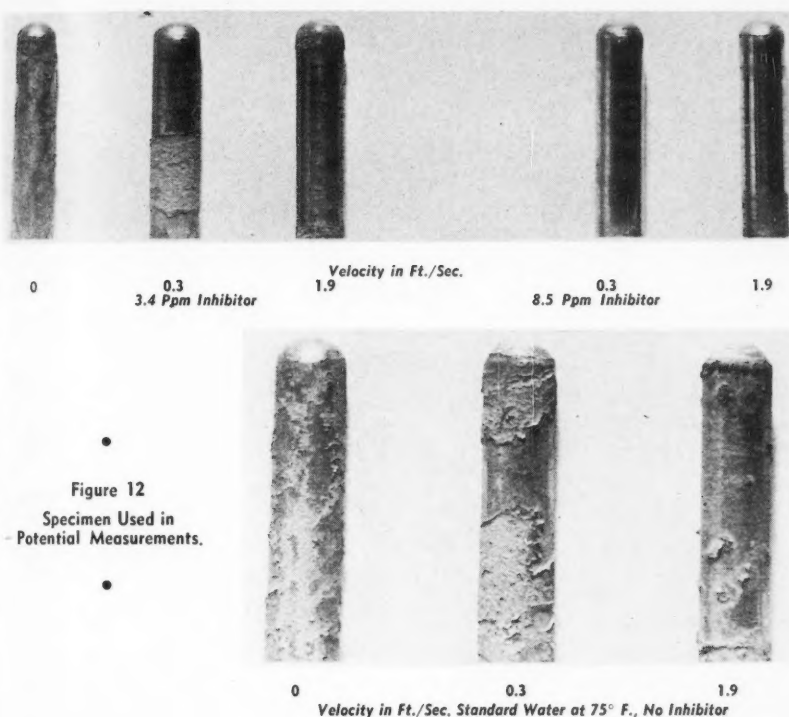


Figure 12

Specimen Used in
Potential Measurements.

fact is shown in Figure 8. In the use of anodic inhibitors it is important that the concentration be not less than this minimum value, otherwise intense local attack will occur at the unprotected points.

The critical concentration of inhibitor is also related to the reproducibility or results. Experience with the test described has shown that, in general, good reproducibility can be obtained. This is illustrated in Figure 9. However, for reasons which have been indicated by Evans,⁵ it should be realized that as the concentration of inhibitor approaches the critical value a lack of reproducibility must be expected.

Different types of corrosion as well as scale and protective film formation which are encountered in practice have been obtained in the laboratory tests. A few of these varied surface conditions are shown in Figure 10.

A desirable feature of the test is that the results are obtained in a relatively short time under non-accelerated conditions. Fraser, Ackerman, and Sands⁶ have supported the validity of a 24-hour test. The justification for a short-time test is undoubtedly related to the fact that the corrosion rate is greatest during the initial stages. Furthermore, it is probable that the inhibiting charac-

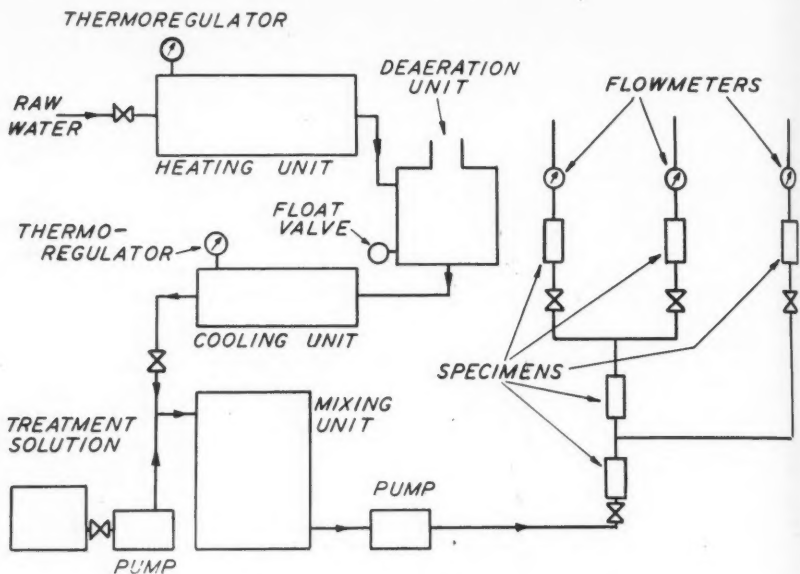


Figure 13—Corrosion Testing Apparatus.

teristics of a material will manifest themselves quickly, if at all.

Not only is the test itself of short duration but the results are easily and rapidly evaluated. Since interest is centered on those conditions where substantially complete protection is obtained it is unnecessary to distinguish small differences between results where corrosion is appreciable. While visual examination, unlike a numerical datum, is not susceptible to quantitative expression there is less chance of erroneous conclusions being drawn from this than from other criteria. Measurement of weight loss, for example, is not only time consuming but, as Darrin⁷ has shown, may not be a reliable basis for evaluating an anodic inhibitor. Visual examina-

tion moreover, permits weight to be given features of local corrosion, which, as previously indicated, are particularly important in evaluating anodic inhibitors.

A useful adjunct to the corrosion results is the information obtained from potential measurements. The factors affecting the potential of a corroding metal have been discussed in detail by Gatty and Spooner.⁸ While the absolute value of the potential usually does not have any special significance, the variation of the potential with time indicates the formation or breakdown of protective films or coatings. Illustrations of this fact are shown by a comparison of the data in Figure 11 with the results in Figure 12. More positive potentials are obtained under

conditions where protective films are formed; falling potentials correspond to the breakdown of such films and to corrosion. The importance of velocity is clearly brought out by these measurements. The potential data thus serve to corroborate information obtained by visual examination of the specimen. The leveling off of the potentials with time tends to substantiate the validity of a short-time test.

It should be remembered that the test which has been described was designed for the particular purposes previously mentioned. For these purposes simplicity and rapidity have been emphasized at the expense of close control of certain variables. It is believed that the control obtained, however, is consistent with the qualitative nature of the criteria used to evaluate the results.

Great care should be exercised in applying the results of any short-

time laboratory test to field conditions. It is intended that the results of this test should serve as a guide to the solution of corrosion problems rather than constitute the solution itself. To this extent the test has proved to be of considerable value. Concentrations of inhibitor found effective in this laboratory test have proved to be of the same order of magnitude as those adopted for use on basis of experience and results in the field. At the present time another corrosion testing apparatus is being used which more nearly duplicates field conditions. A drawing of the apparatus is shown in Figure 13. Inhibitors which have first been subjected to the simple rotating cylinder test are further evaluated in this apparatus. It is hoped that results obtained can be applied with greater certainty to practical problems of underwater corrosion.

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Corrosion Problems in the Manufacture of Soda Ash by the Ammonia Soda Process *

By *Gustave Heinemann**

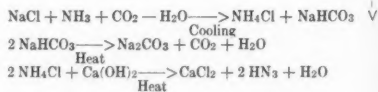
THE PROBLEM of corrosion in the manufacture of soda ash by the ammonia soda process is one which has been, and probably will be for some time, a matter of serious concern. A great deal of time and effort has been devoted to the prevention of corrosion not only because of the effect of corrosion upon the life of the operating equipment but also because of rigorous limits for metallic impurities in the soda ash. As an example of the limits for metallic impurities, it may be cited that commercial soda ash produced by the ammonia soda process will normally contain 0.001 percent or less of iron despite the fact that it is produced almost exclusively in ferrous equipment.

It is realized that some of the problems encountered in the industry are quite specialized and would be, therefore, of academic interest only outside of the industry. Other corrosion problems are of such a nature as to be of general interest to others. This article is an operator's account of some of the experiences encountered by one producer which may be of value to others not only in the soda ash industry but in other fields as well.

Since many persons are not familiar with the process used in the manufacture of soda ash by the ammonia soda process, a brief resume is indicated. In the manufacture of soda ash by this process, sodium bicarbonate is first produced as an intermediate product by the reaction of carbon dioxide with ammoniated salt brine. In this reaction the salt and ammonia are converted to sodium bicarbonate and ammonium chloride, with the sodium bicarbonate being precipitated from the solution upon cooling. The sodium bicarbonate is then calcined to soda ash or sodium carbonate by means of heat and the carbon dioxide which has been liberated is returned to the system. The ammonia is recovered from the mother liquor by the reaction of lime with the ammonium chloride and the free ammonia distilled off for re-use in ammoniating additional brine (Table I).

In the entire process, from the absorption of the ammonia in the brine to the precipitation of the sodium bi-

Table I
Chemical Reactions in Manufacture of Soda Ash



* A paper presented at the Annual Meeting of NACE in St. Louis, Mo., April 5-8, 1948.

* Chief Chemist and Technical Director, Southern Alkali Corp., Corpus Christi, Texas.

carbonate, large quantities of cooling water are used to compensate for the very considerable heats of solution and reaction, and the problem of providing adequate cooling for the process is of primary importance.

With this extremely brief resume it can be visualized that the corrosion problems in this phase of the industry resolve themselves into those on the solution side resulting from the presence of salt brine, ammonium chloride and carbon dioxide, with the corrosion on the cooling water side being of nearly equal importance in many cases.

Classically, the industry leans heavily toward the use of cast iron for its producing equipment and up to the present time, except in a few instances, nothing has yet appeared which gives indication of replacing cast iron despite a number of inherent disadvantages in its use. Although no figures are available to substantiate this statement, it is believed that the soda ash industry uses proportionately more cast iron in its producing units than does any other chemical industry. To illus-

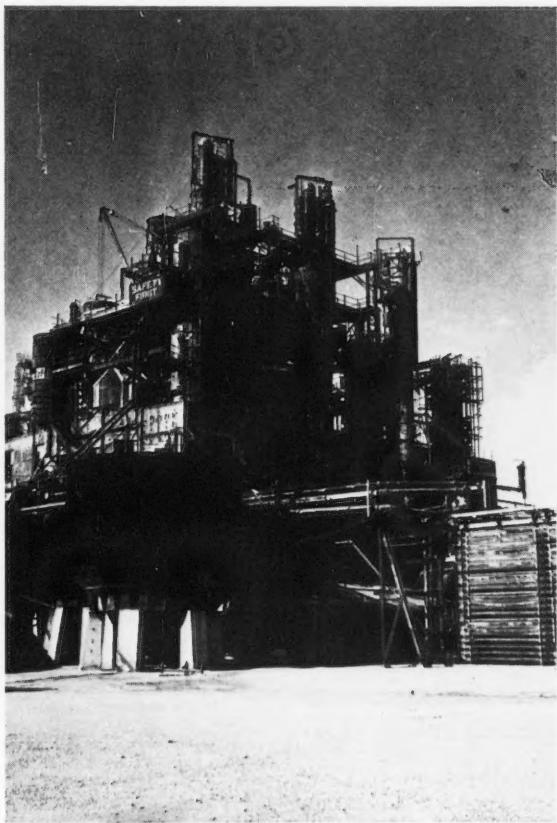


Figure 1—General View of Soda Ash Department.

trate this point, it may be cited that the amount of cast iron equipment in a soda ash plant is estimated to be roughly ten tons per ton of daily capacity. On this basis it may be assumed that there is at least 120,000 tons or more of cast iron equipment in use in the various plants in the United States alone.

Figure 1 shows a general view of the soda ash department of the Southern Alkali plant, illustrating

the magnitude and type of equipment used.

When this plant was built in 1933-34, a 14-inch cast iron line was laid for the transportation of the nearly saturated salt brine to be used in the manufacture of soda ash. The line extends a distance of 61 miles from the brine wells located at the Palagana Salt Dome to the plant at Corpus Christi and is constructed of De Lavaud centrifugally cast iron pipe with joints of the Anthony type, as illustrated in Figure 2, using rubber gaskets. No form of cathodic protection is used.

Within a few years from the time that the line was placed into operation, leaks began to develop at the joints and were found to be accompanied by severe pitting around the bells. These leaks were at first attributed to attack by long line currents.

In the course of the exposure and examination of some joints where large leaks had not yet developed, it was found that a slight seepage of brine accompanied the pitting tendency. This observation gave rise to the theory that the pitting was due to the presence of a concentration cell set up by the strong salt brine in the pipe and a weaker brine on the outside resulting from the dilution with ground water of the brine which had leaked out. As a result of this condition the exterior of the pipe functioned

as the anode and the interior of the pipe as the cathode resulting in the failures noted.

This theory has since been well substantiated in practical observations. It was also relatively easy to account for the slight seepage of brine through the joint which was necessary to set up the concentration cell. In laying the large number of sections of pipe, it was apparent that in some instances where inadequate care had been employed in making the joints, an imperfectly seated gasket or the presence of dirt would produce this effect. As would be expected by this type of failure, the number of such cases diminished with time, although some instances still occur after a period of 13 years.

This experience serves to illustrate how a somewhat altered condition may result in serious corrosion attack from an unexpected source. Were this line to have been used for the transportation of water in place of brine, the loss resulting from the seepage of the liquid through imperfections in the joints

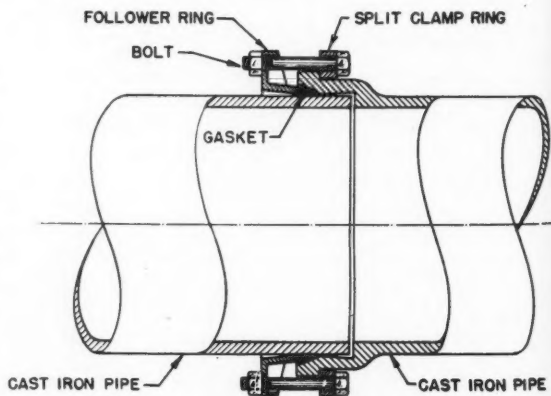


Figure 2—Schematic of Anthony-type Joint.

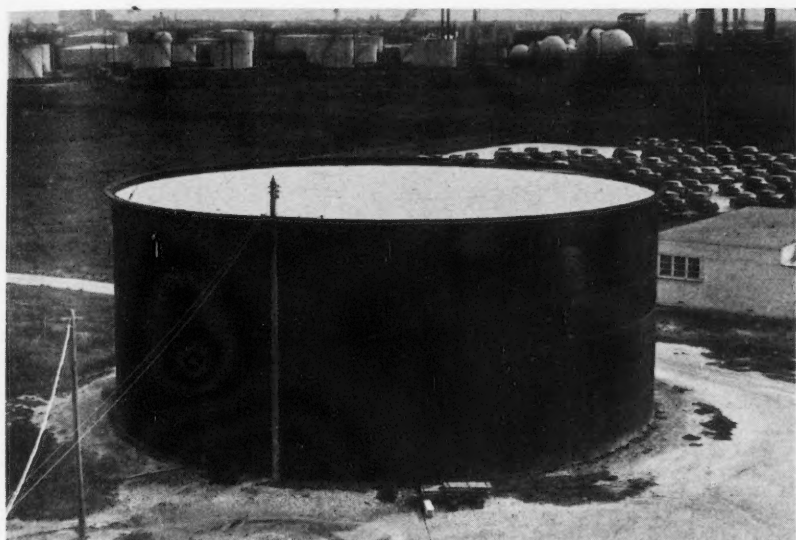


Figure 3—Surface wetted by heavy oil, this 38,000 barrel tank has been in use 8 years without showing appreciable signs of corrosion.

would have been entirely negligible and no material corrosion damage to the pipe would be expected. However, in this instance, where the nearly saturated salt brine was being conducted by the pipe, it became a matter of very serious importance, inasmuch as some leaks resulted in considerable crop damage in the fields through which the line was laid. To eliminate this hazard, all joints of cast iron pipe for this service are now being carefully tested to avoid this condition.

For the transportation of a strong salt brine, the use of cast iron has a great deal to recommend in its economy and resistance to corrosion despite the care required in laying the line. With a proper recognition of the difficulties involved, no trouble should be experienced from this source.

No corrosion problems have been encountered on the inside of the brine line, and the cast iron is in practically perfect condition internally. The extremely low rate of corrosion of the brine on cast iron may appear surprising but the condition of the line after nearly 14 years' use is ample evidence of the suitability of cast iron in this service.

In some instances, steel pipe has been used successfully although there is some indication that it is not especially suitable where high velocities are encountered.

For the storage of a strong salt brine, it has been found that steel tanks are entirely suitable provided that some provision is made for the prevention of "water line" corrosion at the interface between the upper surface of the brine and the atmosphere. Suitable protection can be

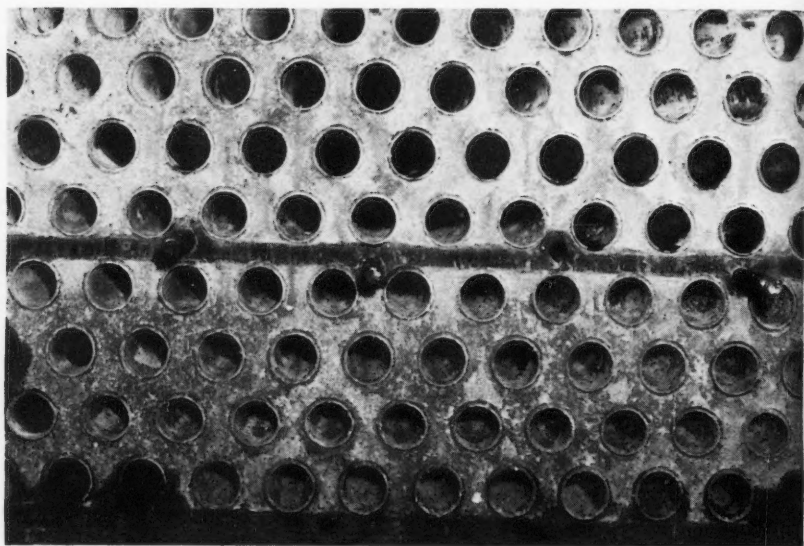


Figure 4—Condenser Tubes After 8 Years Service.

afforded by the use of guniting or by painting the upper portion of the tank from the top to a point below the minimum expected level. Another simple expedient which has been found to be quite serviceable has been the use of a heavy oil which wets the surface of the steel sufficiently to prevent any serious corrosion. As an example, the 38,000 barrel tank illustrated in Figure 3 has been in use for eight years with the only protection being the layer of heavy oil on the surface, yet there is no evidence of appreciable corrosion attack on the tank.

In general, with the exception noted, no unusual problems have been experienced in the handling of the saturated salt brine, cast iron being probably the best material for this purpose where the velocity may be relatively high, or steel for

such uses as in storage tanks or other applications where the velocity is negligible.

For pumping brine it has been found that centrifugal pumps of cast iron construction are very satisfactory and give excellent service. There are undoubtedly some instances where the use of bronze, silicon iron or chrome-nickel steel pumps is indicated although for all instances encountered in soda ash manufacture, the cast iron pumps appear to be entirely adequate.

Corrosion by Ammoniated Brine and Other Ammoniacal Liquors

As in the case of the strong salt brine itself, it has been found that the best, most economical material for handling ammoniated brine is cast iron. It is pointed out that the ammoniated brine as referred to

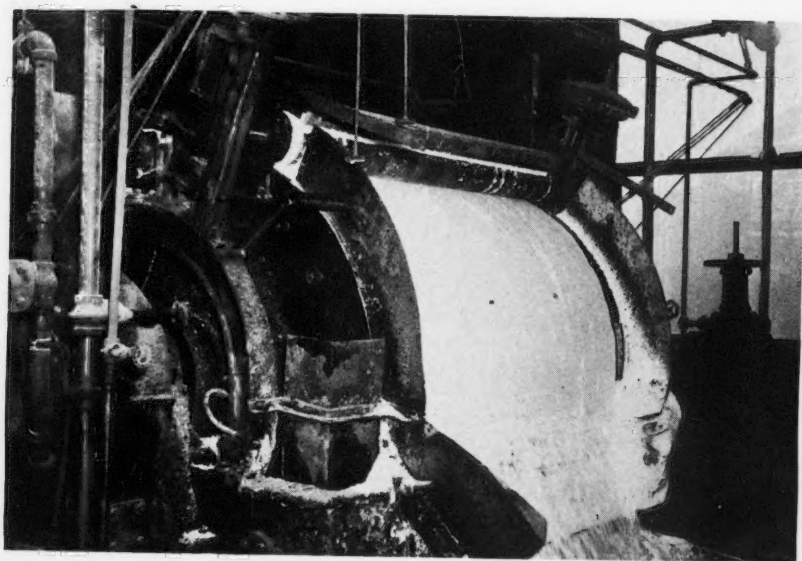


Figure 5—Filter wheel in operation for filtration of sodium bicarbonate from mother liquor.

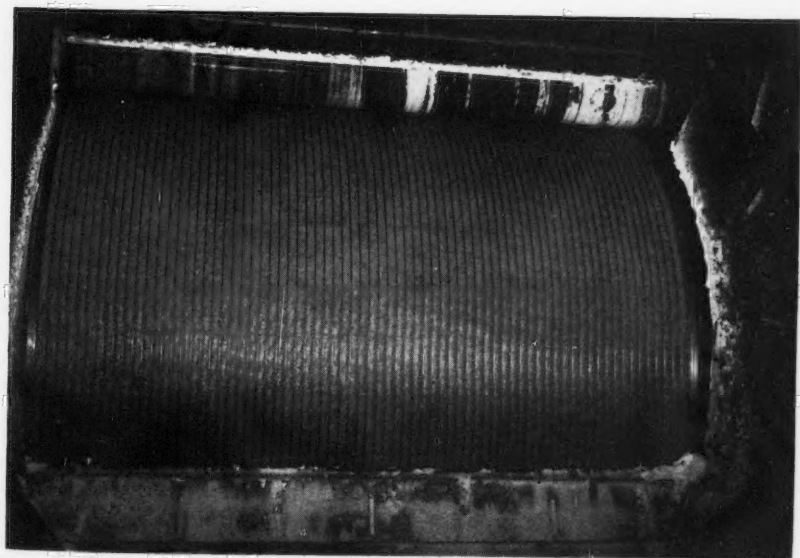


Figure 6—Same wheel as above without load, exposing stainless steel wheel wire and scraper blade.

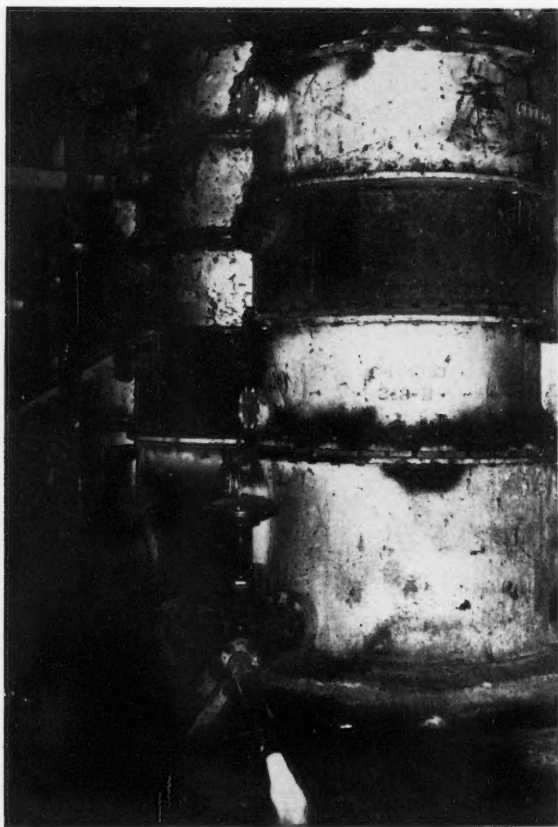


Figure 7—Some Cast-Iron Scrubbers.

here usually contains ammonium carbonate in addition to the ammonium hydroxide. In handling ammoniated brine, the corrosion rates encountered are usually greater than for a straight salt brine. This condition is accentuated by the fact that the ammoniated brine is frequently encountered in the soda ash industry at somewhat elevated temperatures, up to 60-65° C., as compared to the straight salt brine which is usually

handled at atmospheric temperatures.

The common practice for the mitigation of corrosion in soda ash producing equipment is one which will appear to be quite unusual and particularly so to men in the oil refining business. Instead of making every effort to remove sulfides from the system, it is the normal practice in the industry to introduce small, controlled amounts of sulfide into the ammoniated brine. Depending upon conditions of operation in the individual plant, the quantities used will vary between 10 to 200 ppm expressed as hydrogen sulfide. A usual source of the hydrogen sulfide is from the crude ammonia used to replace ammonia losses

in the system, although this practice may vary, with some plants using sodium sulfide or hydrogen sulfide for this purpose.

The presence of the sulfide in the ammoniated brine tends to form a protective film of iron sulfide on the surface of the cast iron which is sufficiently stable to essentially prevent any attack by the brine. It is necessary, however, that the concentration of sulfide be maintained in

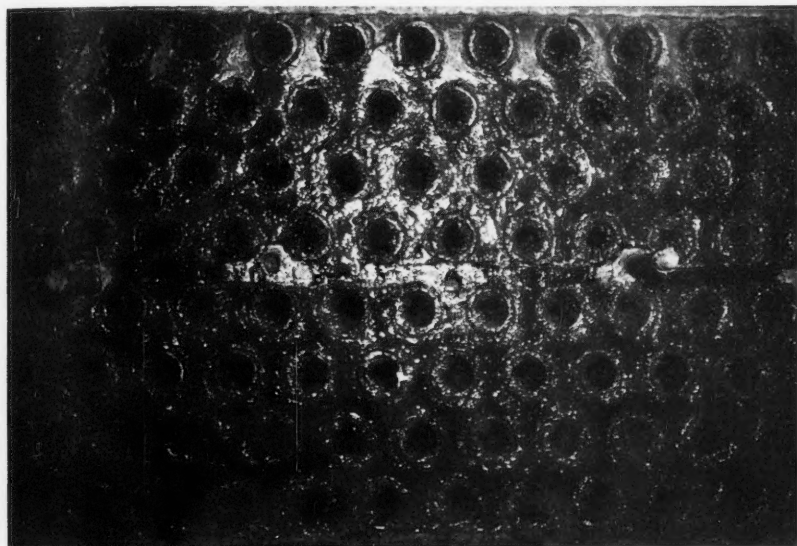


Figure 8—Corrosion by Cooling Water.

order to retain this protective film. It is also necessary to keep any contact of the brine with air at an absolute minimum because of the high susceptibility of the sulfide to oxidation. Illustrative of the effective nature of this protective film is the fact that the soda ash produced by the process is of extremely high purity despite the large amount of contact of the relatively corrosive brines with cast iron.

Although, as has been pointed out, cast iron is almost universally used in the equipment and piping for the manufacture of soda ash, there is one notable exception to this rule. The high resistance of aluminum to ammonia and carbon dioxide in the absence of high chloride concentrations makes its use attractive for the cooling of the hot gases from the ammonia stills. These gases contain-

ing ammonia, carbon dioxide and traces of hydrogen sulfide are cooled to approximately 55 to 60° C. to remove a large portion of the accompanying water vapor before being absorbed in brine.

These coolers, which utilize fresh water as the cooling medium, are constructed of cast iron with a cast iron tube sheet into which aluminum tubes are inserted. Figure 4 shows tubes in this type of unit which are in good condition after eight years and which give promise of many years additional service.

Parenthetically, it may be pointed out that aluminum is now materially cheaper than before the war while all other metals have had major increases in price, making its use economically justifiable in many cases where it might not have been true previously.

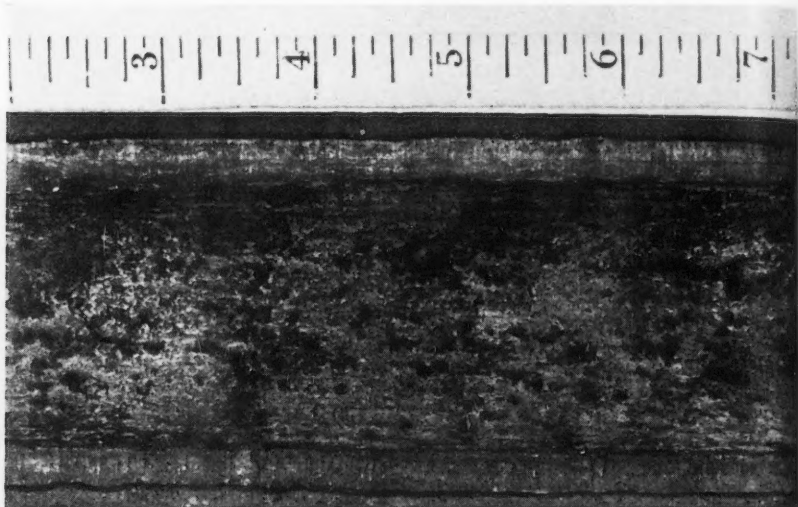


Figure 9—Extreme Example of Sea Water Attack.

It is quite apparent, that because of the presence of ammonia in the system, the choice of materials of construction is quite limited and copper-bearing alloys, in general, are entirely excluded. Since cast iron is quite satisfactory, there are not many places where high priced alloys are economically justified. The various stainless steels have been used with some success in a few instances although tests have shown in many cases that severe pitting has been experienced. One instance is the use of stainless steel as the wheel wire and scraper blades used on the rotary filter wheels for the filtration of sodium bicarbonate from the mother liquor. Figure 5 shows a filter wheel in operation for the filtration of sodium bicarbonate from the mother liquor and Figure 6 shows the same wheel without load to expose the wheel wire and scraper blade. Stainless steel has also been

used successfully to replace cast iron for conducting the hot ammonia gases from the ammonia stills to the gas coolers.

For pumping ammoniacal brines, the same general rules may be applied as for straight salt brine, except, of course, that the bronze compositions cannot be used.

Corrosion by Wet Carbon Dioxide

Another type of corrosion problem experienced in the ammonia soda industry and which may be of general interest elsewhere is that involved in the handling of water saturated gases containing from 40 to 100 percent carbon dioxide on a dry basis with the balance being essentially nitrogen plus approximately 1 percent each of oxygen and carbon monoxide. For this purpose it has been the common practice in the industry to use cast iron although in some instances it has been possible

to use ordinary low carbon steel with satisfactory results. Figure 7 illustrates some cast iron gas scrubbers used to cool and wash compressed carbon dioxide gases for the sodium bicarbonate towers.

This is another instance where the resistance of cast iron is not complete and where an appreciable corrosion rate may be expected but where this material of construction

appears to be more economical than special alloys.

Storage and Handling of Crude Ammonia

Although, as has been mentioned previously, traces of hydrogen sulfides have been used to distinct advantage in the mitigation of corrosion in the ammonia soda industry, the presence of relatively large concentrations of sulfide

in the crude ammoniacal liquor purchased for replacement of ammonia and sulfide lost in the system has given rise to a corrosion problem of its own. Crude ammoniacal liquor may contain from 15 to 25 percent of NH_3 and quantities of sulfide expressed as ammonium sulfide up to as high as 25 percent in addition to the usual impurities such as the phenol and cresol type compounds resulting from the destructive distillation of coal.

Particularly in the higher concentrations of sulfide it has been found that steel is considerably attacked by this liquor, both in the tank cars in which it is shipped and in the storage tanks. As in the balance of the present system, cast iron ap-

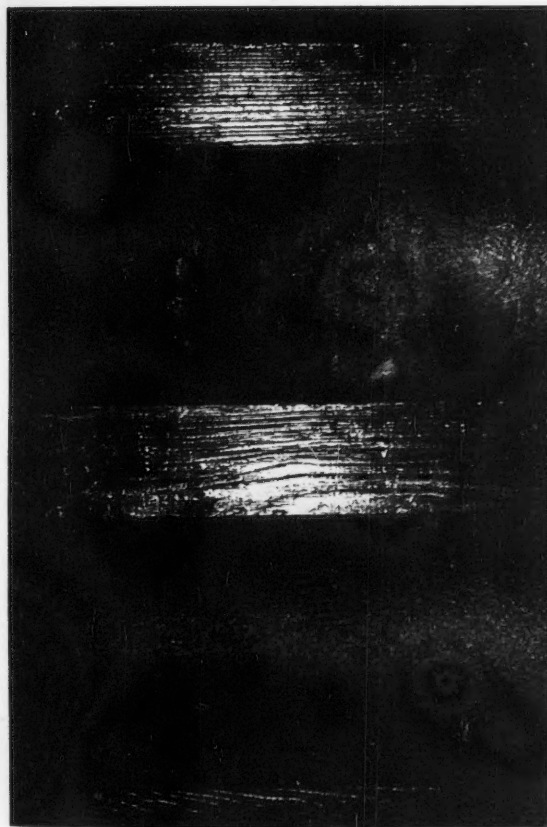


Figure 10—Section of trombone-type coolers in which ammoniacal liquor is cooled by sea water on the outside.

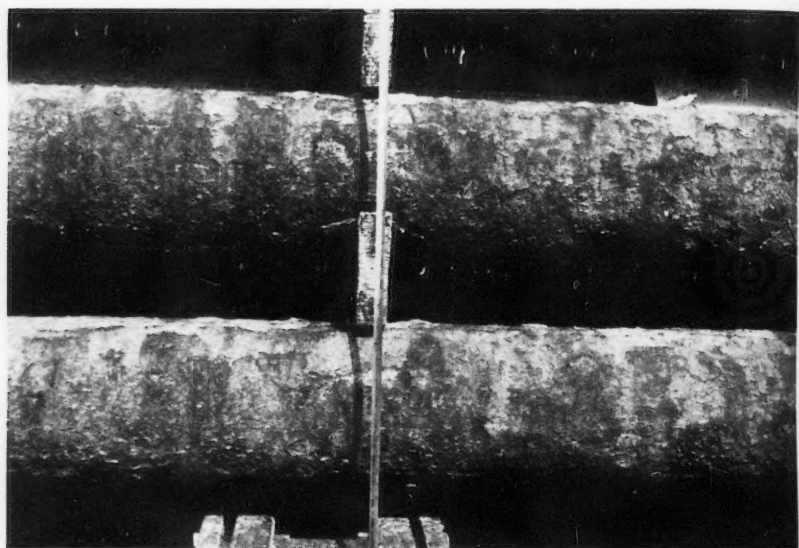


Figure 11—Similar Cast Iron Coolers as Shown in Figure 10, but Not Galvanized.

pears to withstand the effects of the liquor very satisfactorily but does not lend itself to use in the above mentioned applications.

Various types of organic tank coatings have been tried for the protection of the tank cars and storage tanks but completely without success, presumably because of the destructive effect of the impurities in the crude ammonia upon the coatings. Gunite linings have been used successfully in the protection of steel storage tanks but are impractical for tank cars because of the added weight involved.

There are some indications that aluminum can be used in this application very successfully although in the case of tank cars, the cost appears to be prohibitive. This problem is one which has not been completely solved, and offers a challenge

to tank coating manufacturers to supply coatings which would be suitable in this service.

Corrosion by Cooling Water

In the alkali industry the problem of corrosion by cooling water may or may not be a serious problem depending on the nature of the water employed. Plants fortunate enough to have adequate supplies of a relatively non-corrosive fresh water do not experience appreciable difficulty from this source. However, those plants which employ sea water or brackish waters for process cooling find the problem to be very serious. An example of the magnitude of this problem may be seen in the fact that as much as 50 million gallons a day of brackish sea water are used by our plant for cooling purposes. This water is derived from a ship channel

located at the end of Corpus Christi Bay where it is frequently diluted with fresh water run-off from the Nueces River. A common solution to this problem in many industries would involve the use of the various copper alloys such as cupronickel which has been found to give excellent service in such waters.

Being restricted in the use of this material because of the effect of the ammonia in the process upon copper-bearing alloys, the use of cast iron tubes and piping has been almost universal. An illustration of the extent of this problem can be seen in Figure 8, showing the corrosion on the water side of one of the cooling boxes in one of the units in the soda ash department.

As a result of this corrosion, it is necessary to mechanically clean the tubes at least every three or four months and even under that circumstance the heat transfer coefficient is very seriously reduced. An extreme example of the effect of sea water attack in this service may be seen in Figure 9, which shows half of a section of a cast iron tube which was removed from service after approximately five years' usage. This particular specimen had been cleaned prior to removal because of a leak which developed during the cleaning operation. The specimen was then allowed to dry, causing a slight separation of the graphitized layer from the remaining parent metal. An inspection of this specimen revealed the seriousness of the problem, which to date has not been completely solved.

Internal coating of the tubes has been tried but with indifferent success because the inherent roughness of the cast iron renders ade-

quate surface preparation difficult, if not impossible. Tubes coated commercially with a baked phenolic resin coating have shown severe tuberculation within nine months after being placed into service, presumably by reason of exposure of the metal through pin points projecting through the coating after being placed in service.

If a relatively smooth internal surface were obtainable on the cast iron tubes, it is felt that such a coating would provide an excellent answer to this problem inasmuch as the coatings themselves have excellent resistance. In one test on six selected tubes where the internal surfaces were relatively smooth, the coating is in excellent condition after three years' service but when a random selection of tubes was coated, early failure was experienced. One inherent disadvantage of this type of protection is a reduction of approximately 30 percent in the initial heat transfer coefficient as compared to that for a new uncoated tube. After a year's time, the advantage of the protective coating becomes evident and the heat transfer coefficient will then be as much as 50 percent greater than for an uncoated tube with the same service.

The use of galvanizing for internal protection has also been considered and although the water side of the tube would be protected by the galvanizing, it is felt that the galvanizing operation would remove the natural protective layer on the outside which is assumed to add much to the resistance of cast iron toward ammoniacal brines. For this reason little actual work has been done in this direction.

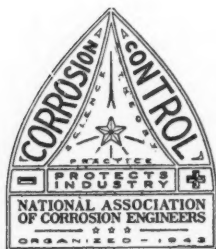
In some services in the system

where cast iron is protected from the action of the ammoniacal brine by a slight scaling of calcium carbonate, galvanizing has been found to be very beneficial in protecting the water side from corrosion. Figure 10 shows a stack of trombone type galvanized coolers in which ammoniacal liquor is cooled by sea water on the outside and which have been in service for a period of approximately three years. In contrast, Figure 11 shows similar stacks of cast iron coolers in identical service placed into operation at the same time but which were not galvanized. As a result of the galvanizing, it is anticipated that at least a 30 percent increase in useful life can be obtained from this type of equipment, increasing the normal life from nine years to twelve years where sea water is used as the cooling medium.

For the transportation of sea water, cast iron has been used extensively but has the serious disadvantage of requiring annual cleaning in

order to minimize the pressure drop resulting from tuberculation of the cast iron. A more satisfactory solution to this problem appears to lie in the use of cement-lined pipe which in several installations has given excellent service and it is felt that any future installations will involve the use of this material. Obviously, by reason of the insulating effect of the cement lining, this cannot be considered for coolers and in similar applications where heat transfer is a factor. The use of Transit pipe is also very attractive where sea water is being transported and gives evidence of excellent service.

It is hoped that this account will be of some value in the solutions of the many corrosion problems encountered in the chemical industry and at the same time point out a few of the problems which still exist where an economical solution will be welcomed.



Corrosion of Underground Power Cable Sheaths*

By L. F. Greve*

Introduction

SEVERAL methods employed by a large utility company for mitigating extremely troublesome corrosive conditions caused by local, concentration and galvanic cells on the underground cable system are described in this article.

The number of cable failures attributable to all types of corrosion on this utility company's system has been kept below 1.0 per 100 miles of cable per year. The average for 20 years is 0.41 failures per 100 miles of cable per year. This is considered a very good record. However, in the past five years the problems caused by concentration cells have been increasing and will continue to increase as the rails are removed in connection with the proposed conversion of many street car lines to buses. Troubles caused by galvanic cells, while currently presenting difficulties, are not expected to increase since they are mainly within the system itself and may therefore be controlled through design.

Local Cells

Local cells are confined to those in which the potential difference exists between adjacent parts of the same metallic surface in the same electrolyte due to lack of homogeneity in the metal or to abrasions in the metal surface. Cable sheath corrosion from this source has been negligible and no failures have been attributed to it.

Concentration Cells

Concentration cells, or those in which the potential difference is due to dissimilar and adjacent electrolytes connected together by a uniform metal surface, are more of a problem. The most common condition in which these cells occur in our system is found where different backfills such as clay and cinders come in contact with the conduit run at locations where the sheath potential is near zero. Corrosion attributable to these conditions has been very troublesome and extensive research work by experienced investigators is necessary to determine the extent of the corrosive action and the most practical and economi-

*A paper presented at the Annual Meeting of NACE held in St. Louis, Mo., Apr. 5-8, 1948.

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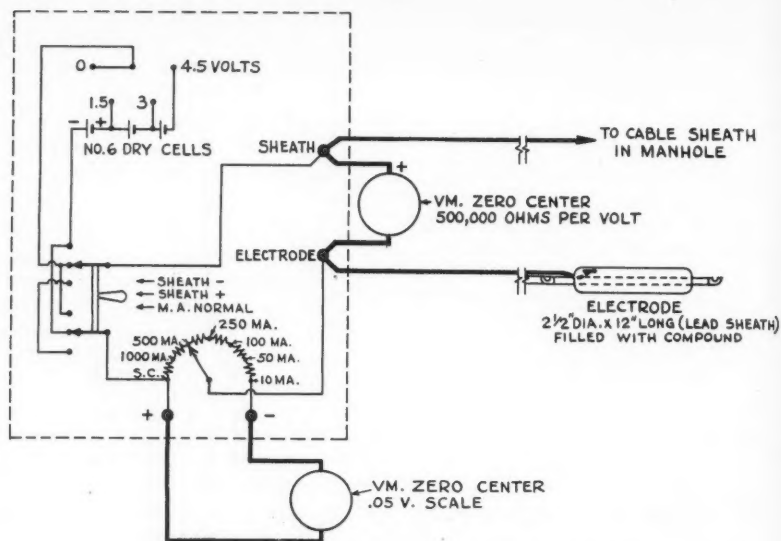


Figure 1—Schematic of Equipment Used in Duct Survey.

cal method of its elimination. As mentioned before, an increase in this form of corrosion is expected as more cathodic protection is lost by the removal of rails.

The fact that the electrode potential of a cable sheath varies with different electrolytes and with different concentrations of the same electrolyte makes the mitigation of corrosion attributable to concentration cells difficult. The conditions under which any large underground cable system has to operate makes it almost impossible to eliminate changes in the environment, which may cause variation in the electrolytes surrounding the cables. However, in those cases where the environment can be changed by replacing the fill with clean, uniform, high-resistant soil, good results have been obtained. This method is obviously

best because it removes the source of the trouble. In some cases it is more feasible economically to apply cathodic protection to the affected sheaths. This consists of applying a voltage from an outside source in such a way as to make the cable sheaths sufficiently negative to overcome any positive conditions that may exist due to local concentration cells.

Another method sometimes used when only a few cables are involved consists in actually setting up a galvanic cell, by making use of the electrode potential that exists between lead and one of the less noble metals in the electromotive series. The cable sheaths of the affected length are insulated from the rest of the cable system and are connected to buried ground-plates or rods of metal electrically negative

to lead. Under these conditions, the grounding metal becomes the anode and the cable sheath the cathode of a galvanic cell, resulting in a condition where the grounding metal is subjected to corrosion. In this type of mitigation on electric power cable systems, the continuity of the cable sheath circuit is maintained by bridging the isolated section of cable sheaths with a bond cable.

Galvanic Cells

Galvanic cells are defined as being caused by the electro-chemical potential existing between two different metals connected together and immersed in an electrolyte. In our system the two metals are usually lead and copper or brass. The potential may be as high as 0.6 volt, with the lead anodic. The general practice of power companies is to connect the cable sheaths to the station ground bus. This practice results in a permanent short circuit of the galvanic cell.

Following are several interesting cases of cable sheath corrosion.

Case No. 1—Cable In Street Conduit

A cable failed after three years' service and was found to be seriously corroded near one end of the length. Routine electrolysis tests did not adequately reveal the condition. However, a duct survey made along the length of conduit showed the cable sheaths to be positive to earth for a portion of the length. A duct survey consists of taking a series of voltage and leakage current readings at four-foot intervals along the conduit between the cable sheaths in the manhole and a lead electrode

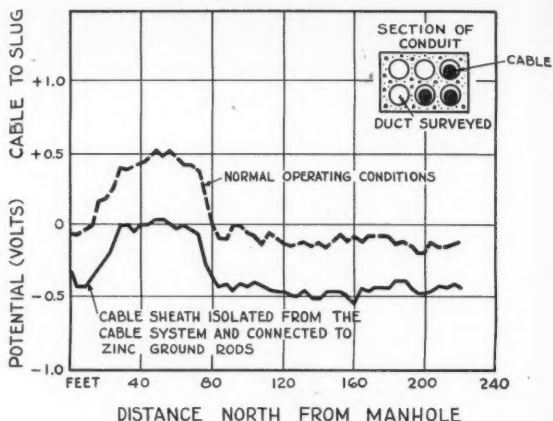
pushed into a vacant duct.

Figure 1 shows the equipment used in making the duct survey. Our testing department made up a kit containing some dry cells, resistances, switches and binding posts, which greatly reduced work involved to set up the equipment for making the test. As shown, two voltmeters are used with the test kit and a standard electrode made of lead. The d-c potential between the cable sheaths and the electrode and the leakage current is indicated by the meters and the resistance may be calculated from the readings recorded. This same equipment is also used to determine both anodic and cathodic conditions due to stray railway currents.

Where tests indicated the highest positive potentials, an excavation was made and the conduit exposed. The conduit was about seven feet below the surface of the street and located in clay soil, but the fill, over and down to the conduit, consisted of cinders. Voltage readings in the excavation showed the sheaths averaged 0.5 volt negative to the cinders and 0.2 volt positive to the clay. This difference of potential between the cinder and the clay fill indicated the positive condition of the sheaths was caused by a concentration cell.

Tests were made to determine the possibility of overcoming the concentration cell by increasing the electrical drainage of the cable sheaths. It was found that it would be necessary to drain an additional 35 amperes from the sheaths at this location to maintain them slightly negative to earth throughout the length of conduit. From an economical standpoint, this method of miti-

Figure 2—Duct survey with and without cathodic protection.



gating the trouble was not practical.

The positive condition was eliminated by isolating the cable sheaths in the length of conduit from the system by means of insulating sleeves, connecting the isolated section to zinc ground rods in each of the two manholes, and bonding the cable sheath system around the isolated section.

Figure 2 shows the sheath potentials along the conduit. From near the manhole to 80 feet into the duct the cable sheaths were found to be

as much as 0.5 volt positive to earth. This positive condition was eliminated by the zinc ground rods.

After ten years service with the zinc rods, the cable sheaths were found to be as much as 0.2 volt positive to earth again, indicating that the zinc rods were deteriorating. The zinc rods were recently replaced with magnesium anodes. A sketch of the connections is shown in Figure 3. The method of installing the magnesium anodes is shown in Figure 4.

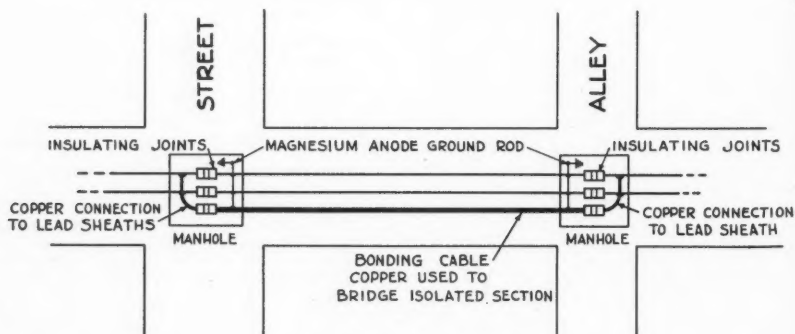


Figure 3—Bonding Diagram.

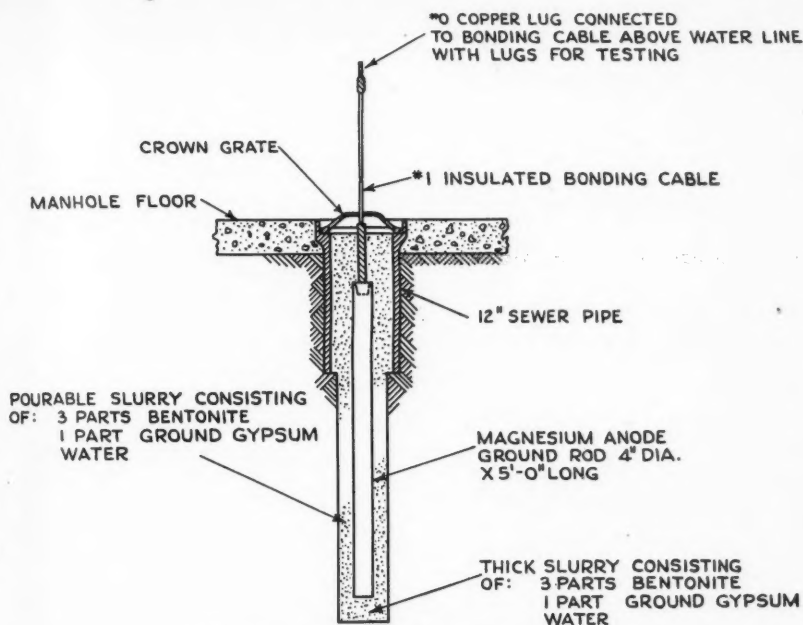


Figure 4—Method of installing Magnesium Anode.

A 12-inch sewer pipe is installed in the floor of the manhole as shown. Then an 8-inch hole is bored into the earth through the bottom of the tile. A magnesium anode five feet long and four inches in diameter is installed with a slurry of three parts bentonite, one part ground gypsum and water. A regular crown grate sewer cover is placed over the opening in the floor of the manhole.

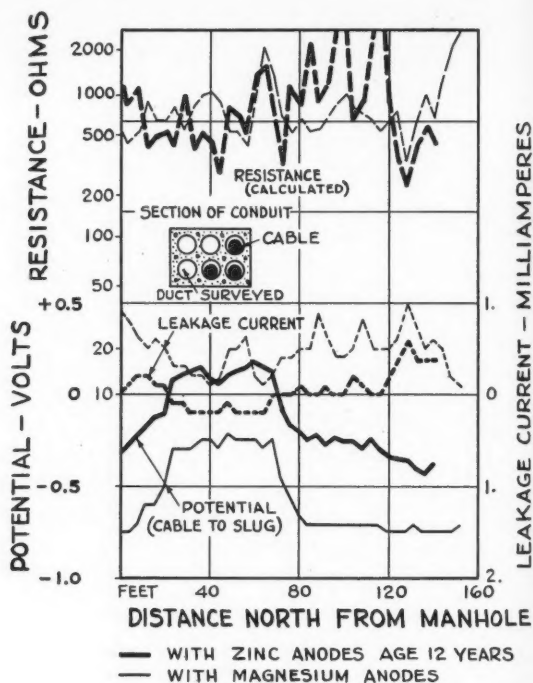
The complete results of a duct survey made before and after the magnesium anodes were installed are shown in Figure 5. This shows the sheath potentials, the leakage current and the resistance at a location which has been under periodic observation for over 12 years.

Case No. 2—Generating Station

Two cables failed because of corrosion of the lead sheaths in conduits on a generating station property. The conduit consisted of three duct banks containing a total of 45 cables. Routine sheath voltage readings in the manholes indicated that electrolysis conditions were satisfactory and chemical analyses showed the water from the conduit not to be particularly corrosive to lead. Another cable, which had been in service only seven years, was removed for inspection of the sheath and was found to be seriously corroded.

A series of duct surveys made at various locations at this generating station indicated that many cable

Figure 5
Duct Survey with
Cathodic Protection.



sheaths in the conduit were as much as 0.2 volt positive to earth. Four excavations were made. In general, the conduit was in sandy muck soil; however, cinder fill in many locations extended down to and in some places below the top of the conduit.

Voltage readings made in the excavations showed the cable sheaths to average about 0.5 volt negative to the cinders and to be slightly positive to the sandy muck soil. This difference in potential between the two materials adjacent to the conduit and the fact that considerable copper was used for grounding purposes indicated that the corrosive condition was a combination of concentration and galvanic cells.

Test excavations were made at other locations on the property and duct surveys were conducted to determine the extent of the corrosive area. It was found that 18 conduit runs were involved, some of which are over 1200 feet long containing about 250 cables.

After extensive tests and careful consideration of all the factors involved, it was decided that the most feasible method of reducing the corrosive condition would be to apply cathodic protection to the cable sheaths. This was done in steps by installing 27 ground plates at intervals along the conduit runs and connecting them individually to an insulated 1,000,000 cm bond cable,

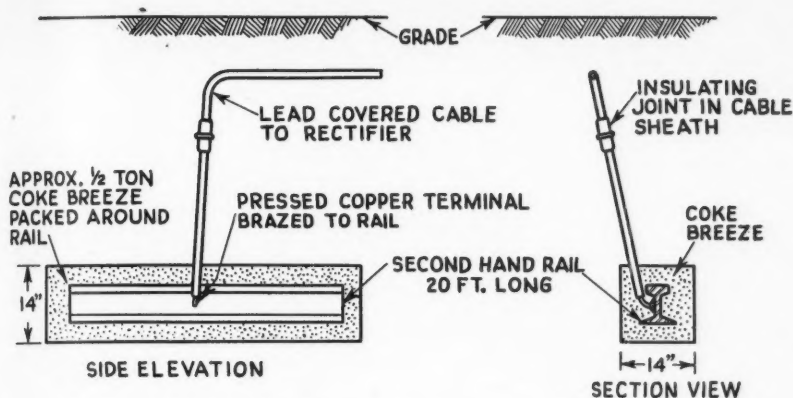


Figure 6—Method of installing Ground Plates.

which was connected to the positive terminal of a rectifier. The ground plates, as shown on Figure 6, consisted of 20-foot steel rails buried from five to ten feet below the surface, each embedded in one-half ton of finely pulverized coke. In general the ground plates were spaced about 100 feet apart and not closer than ten feet to any one of the cable runs.

The rectifier was designed to supply d-c voltage of from one to six volts in steps of one-tenth of a volt. Tests established that in order to maintain the cable sheaths negative to earth in the conduits, it would be necessary to apply 4.8 volts with a total current flow of about 55 amperes or an average of two amperes per ground plate.

Figures 7 and 8 show the voltage between the cable sheaths and earth along two of the conduit runs before and after cathodic protection was applied. These figures also show the relative position of the ground plates with respect to the conduit runs.

Extensive tests indicate that practically all of the cable sheaths on the station property are now negative to earth and that the serious corrosive conditions which existed have been eliminated.

Case No. 3—Brass Entrance Pipes

In a distribution station a large number of brass entrance pipes had been installed. From a design standpoint, the non-magnetic brass entrance pipes would reduce induced losses on the many single-conductor cables entering here, and in addition, would be more durable than iron pipes. However, from a corrosion standpoint, the two metals, brass and lead, form a galvanic couple in the presence of moisture, with the lead sheath being anodic.

To correct this, since the brass entrance pipes were already installed, it was recommended that a protective lead sleeve be wiped on that portion of the cable passing through the brass entrance pipe. This would

FIGURE 7

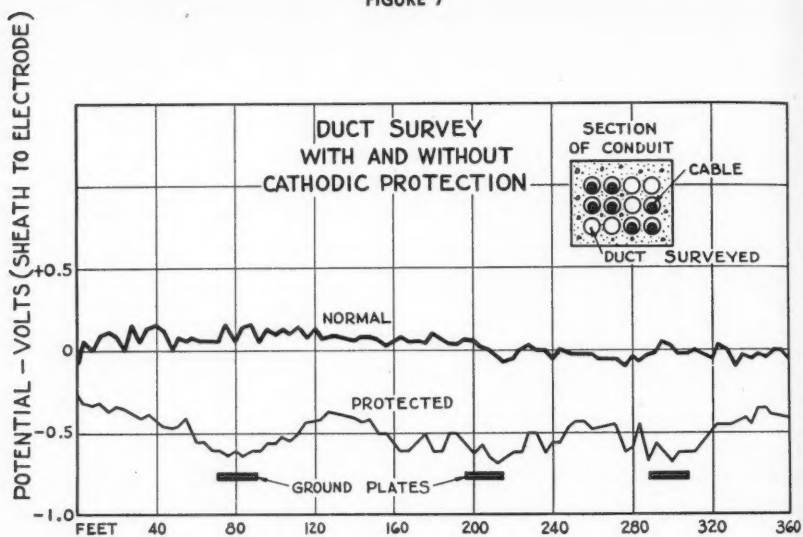
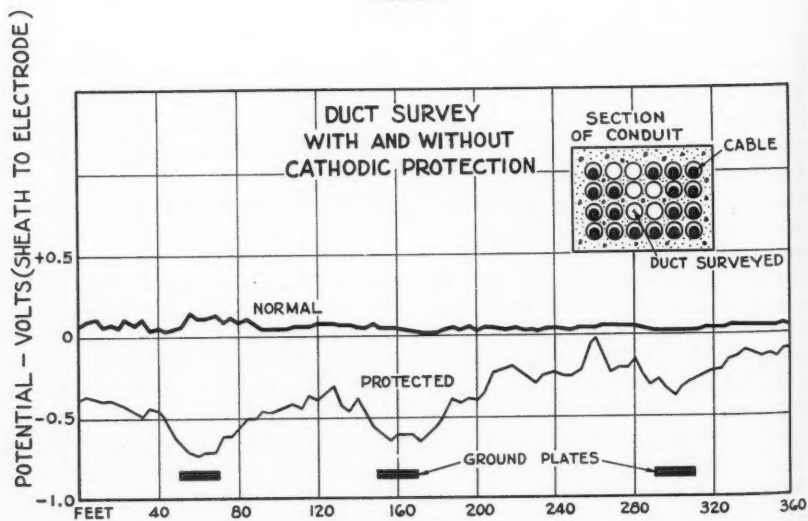


FIGURE 8



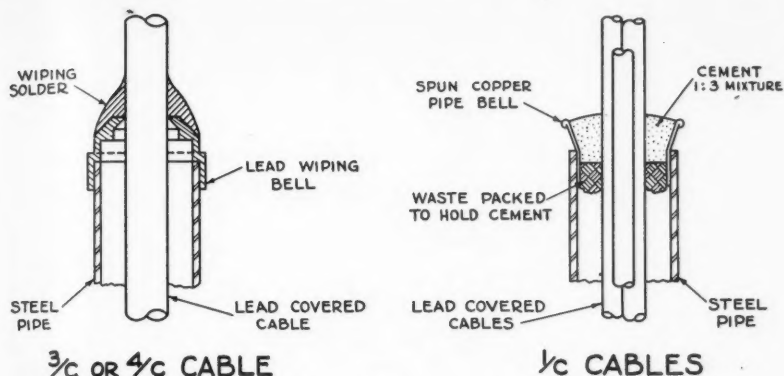


Figure 9—Method of installing Pipe Bells.

not eliminate the galvanic couple, but it would protect the cable sheath by virtue of subjecting the lead sleeve to any galvanic action present.

Two circuit cables were installed in these brass entrance pipes before the recommendation for the protective lead sleeve was made.

Approximately ten years after installation one of the two cables installed without the protective lead sleeve failed because of corrosion. The sheath was found to be seriously corroded around the point of failure, which was three inches inside the brass entrance pipe. There were also a number of small pits along the bottom of the cable where it made contact with the brass entrance pipe.

On the basis of this failure an examination was made of the other cable sheath without a protective lead sleeve, and a number of cables with protective sleeves. The cable sheaths protected by a lead sleeve were found to be in good condition, but the unprotected cable sheath and

the protective lead sleeves were found to be pitted. In some cases the pits were as much as 40 mils in depth. The use of protective lead sleeves in brass entrance pipes had, in this case, protected the cable sheaths from serious corrosive attack.

In order to slow down the corrosive attack on the protective lead sleeves it was recommended that cable lubricating compound be pumped in through the plug on the wiping cap of the brass entrance pipe. This would fill the space between the lead sleeve and the brass pipe, minimizing contact areas and excluding moisture.

One other cable failure attributable to corrosion of lead sheath unprotected by a sleeve in a brass entrance pipe occurred at a sub-station. Since that time, a number of locations where brass entrance pipes may have been installed were inspected. On any old installation of brass entrance pipe it is our standard practice to install a protective lead sleeve on the cable, and pump grease



Figure 10—Corrosion attributable to local cell.

into the space between the sleeve and pipe. On new installations, where the standard galvanized iron pipe is not satisfactory, a lead alloy entrance pipe is now used to prevent this type of corrosion.

Case No. 4—Pipe Bells

During the past five years some 20 cases of cable sheath corrosion were found at the top of the iron pipe on cable poles. Starting in 1926, a spun copper pipe bell was used at the top of the iron pipe. Cement was used in the bell to support and center the cable and to keep out moisture.

In many of these cases the entire circumference of the cable sheath was found to be seriously corroded for about two inches where the cable sheath was in contact with the cement in the copper bell. The cor-

rosion products consisted of orange-colored crystalline deposits, which in some cases extended all the way through the lead. A number of cases resulted in cable failures.

There are two things wrong with this installation. First, the copper bell should not be used because of the probability of a galvanic cell between copper and lead. The cell is short-circuited by the cable sheath in contact with the pipe which in turn is in contact with the bell. Second, cement should not be used because of the strong alkaline solution resulting from water seeping through the cement forming the electrolyte. A new design consisting of a cast lead wiping bell has been used for several years on new and replacement jobs.

About three years ago a maintenance program was started which

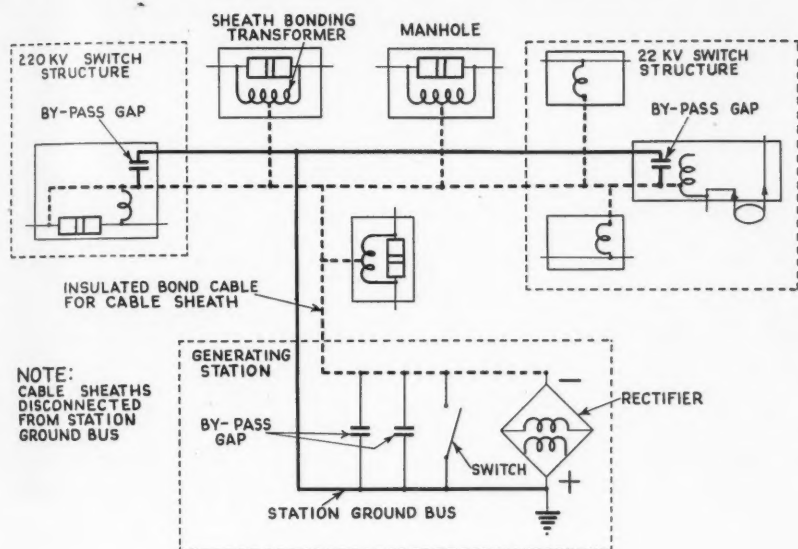


Figure 11—Cathodic Protection System.

covers inspection of cables with spun copper bells and for replacement with wiped lead bells. Figure 9 shows the two bells. Several examples of cable sheath corrosion are shown in Figure 10.

Case No. 5—Generating Station

Another and more serious case of cable sheath corrosion was encountered at a generating station located in the country far removed from stray railway currents. Two generator leads failed because of corrosion. Ten cables were removed for inspection and found seriously corroded.

A complete electrolysis investigation, including many duct surveys and inspections, was made.

The cause of the trouble was attributed to a large-scale galvanic

cell. The cable sheaths were connected to copper covered ground rods in each manhole. They were also connected to a ground bus consisting of bare copper cables buried in the ground and connected to many 30-foot copper covered ground rods. There were also many bronze armored cables buried in the ground between the station and the transformer terminal. Duct surveys showed the cable sheaths to be as much as 0.6 volt positive to earth.

The first step taken in mitigating this condition was to disconnect the copper covered ground rods in the manholes. The next step was to apply cathodic protection similar to that used in a previous case. However, during a temporary installation it was impossible to force current to flow from a ground plate to

the cable sheaths because of some reinforcing wire in the concrete envelope around the conduit line. Both the cable sheaths and the reinforcing wire were connected to the ground bus.

In order to apply cathodic protection to the cable sheaths it was necessary to disconnect the cable sheaths from the ground bus and install a rectifier between the cable sheaths and the ground bus, as shown in Figure 11. The cable sheaths were connected to an insulated bond cable connected to the negative terminal of the rectifier. A short circuiting switch was installed from the bond cable to the ground bus so that the switch could be closed (with the rectifier shut down) while men work in the manholes. For normal operation the rectifier supplies 2.5 amperes at 6.5 volts.

To provide a path for fault currents in case of a cable failure, four by-pass gaps were installed at various locations between the bond cable and the ground bus. Figure 12 shows details of the by-pass gap. These by-pass gap units utilize a series lamp cutout for the gap itself, which is backed up with a heavy copper removable disc. These discs may be replaced if the gap should fuse. Our tests indicated that these gaps would blow at 100 volts plus or minus 10 percent when under pressure of 100 pounds. The springs

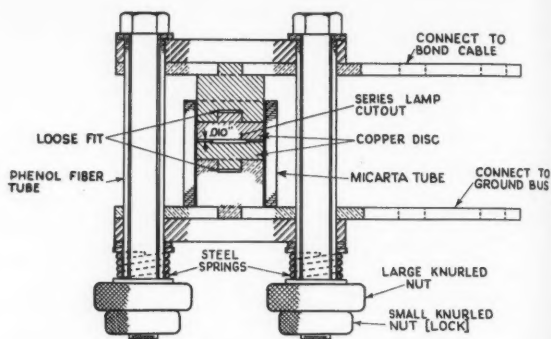


Figure 12—By-pass Gap.

shown and the stud insulating bushings with an overall length of 5 7/16 inches gave the desired pressure. We have had one cable failure which was not caused by corrosion. However, the sheath gaps operated properly and the rectifier was not damaged.

Because of some trouble the electric utilities are having and because of the interest shown in M. C. Miller's paper, the Electrical Engineer's Responsibility for Recognizing Corrosion as a Factor in the Design of Electrical Structures, (Corrosion, Vol. 3 No. 7, 341-346, July, 1947) the following suggestion is made.

It involves the following \$64 question: Since lead covered cable sheaths are usually connected to the ground bus at stations and sub-stations and thereby form a large scale galvanic cell, what metal should be used for grounding purposes in place of copper at generating stations and sub-stations? This may be the subject for a committee of NACE to study.

DISCUSSION

By F. E. Kulman*

Cable corrosion in cinder-filled sections may often be very severe as Mr. Greve indicates. The path of the electric current responsible for sheath corrosion in such areas may be pictured somewhat as follows: Because of the difference in fill surrounding the duct bank, the cable sheath tends to be cathodic in the duct sections installed in natural types of soil, and anodic in the section installed in cinder-fill. At the latter location, current tends to be discharged from the sheath through the duct wall to the cinders, causing electrolytic corrosion of the lead. The voltage of the cell approximates 1.0 volt. If, as happens on a power cable system, the electric cable sheath is connected electrically through grounding connections to a bare metal (water) pipe in contact with the same cinder bed, this electric connection, of relatively low ohmic resistance, short circuits the electrolytic resistances of the natural soil and of the duct wall in the cathodic area. Substantially the entire voltage of the electrolytic cell is thus impressed across the duct wall in the anodic area. The electrolytic path is then reduced to the duct wall in the anodic area; the cable sheath in the duct is the anode, and the carbon in the cinders is the cathode, of a short-circuited lead-carbon galvanic cell. It is thus not unusual to

measure potential differences of 0.7 to 0.9 volt between cable sheath and the duct wall under such circumstances.

The corrosion rate of lead-sheathed cable installed through cinder-filled areas, as in other cases of anodic corrosion, depends greatly on the resistance through the duct wall. In dry locations, cable has operated for periods of 15 to 20 years or more without failure. Contrariwise, cable has failed in two to three years where the ducts were saturated with tide water of approximately 100 ohm-centimeters resistivity. Replacing the cinder fill with clean, uniform soil of high resistance has been found to be effective in reducing the corrosive attack. This method, however, is very expensive, especially if long runs are to be excavated. Mitigation of the corrosion can be also obtained by installing cable with its sheath protected by a synthetic hose jacket of neoprene or polyethylene.

Another type of corrosion, which is expected to increase as trolleys are replaced by buses, is the so-called "duct corrosion." This is caused by electrolyte conditions existing within the duct and is usually associated with low duct resistance. Differential-aeration and concentration cells, when occurring in the duct, are included in this category. Local cells are likely to form on the cable

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sheath if the cable is only partially submerged in the duct water. The more severe corrosion is likely to occur at the water line. The corroded area usually is a zone approximately $3/4$ inch to $1\frac{1}{2}$ inches wide on the bottom of the cable, and the attack may be in the nature of intercrystalline corrosion. The application of corrosion preventive grease has been found to be of benefit and is recommended for cable replacements or new installations in such low resistance sections.

The question of local cells arises particularly with respect to re-installed cable. This is cable which is withdrawn from a duct, reconditioned, and redrawn into another duct, not necessarily at the same location at which it was originally installed. Such re-installed cable has been found to have a shortened service life as compared with cable not removed from its original installation. It is noted that the used cable, in starting the second phase of its service life, has already been subjected to three pullings with attendant scoring and abrasion, and six reelings or unreelings. This represents

three times the handling a new cable receives. It is therefore likely that the extra handling of the cable gives rise to local corrosion cells on the sheath which result in shortened service life of the cable.

Sheath inhomogeneities are not usually considered important in cable corrosion. Their importance, at present, is greatly overshadowed by the other corrosion factors mentioned by Mr. Greve. These other factors are found to predominate where the service life of the cable is comparatively short. However, it is extremely questionable whether the question of sheath inhomogeneities can be dismissed entirely. This is a factor which deserves the attention of cable manufacturers. If, by proper control of sheath constituents, the average life of cable could be increased, the additional expenditure of a few percent for such a sheath would be economically justifiable. It is becoming more apparent that a need exists for sheaths which are homogeneous when installed in underground duct, and efforts to provide such sheaths should be encouraged.

By Irwin C. Dietze*

I was very much interested in the ingenious lead wiping bell developed by Mr. Greve to cap the steel conduit of underground risers. The cap also provides a convenient means of bonding the cable sheaths to the iron conduit.

The Los Angeles Department of Water and Power grounds their cable sheaths to the galvanized iron riser pipe by soldering a $1/8$ inch by 2 inch lead strip to the cable sheaths about 6 inches above the top of the iron conduit and then soldering this lead strip to the iron conduit. In the case of secondary cables the lead

* Electrolysis Engineer, Dept. of Water and Power, City of Los Angeles, Calif.

strip is also soldered to the copper conductor of the neutral cable at the same point. Since the neutral conductor is grounded to the water pipe at each consumer's service (local city ordinance) this method provides a good ground for the riser conduit and lead cable sheaths and also prevents a flash over or burn during faults or cable failures between the lead sheath and the inside of the conduit due to poor contact.

We have also found the same type of orange and yellow colored crystalline deposits of lead oxide on cable sheaths where cement was used to seal around the cable at the mouth of the ducts in manholes. A putty type of material known as "Duct Seal" works very satisfactorily for

sealing out water and does not corrode the lead sheath.

Mr. Greve has a good suggestion in that the NACE appoint a committee to investigate the use of another metal in place of copper for grounding generation and sub-stations to prevent the galvanic action between copper and lead.

The use of sheath grounding cells between the station ground and the lead cable sheaths may be one solution, as employed by the Department of Water and Power on their 34.5 Kv. and 138 Kv. cables which are protected with cathodic protection. The cell provides a small back emf and also acts as a valve to prevent the cathodic current from entering the cable system through the receiving station copper ground.

By A. Bodicky*

The problem of corrosion protection is accomplished by preventing electric current from leaving the metallic structure through an electrolyte. This can be done by either insulating the metal from the electrolyte or by maintaining it at a negative potential with respect to the surrounding media. This second method is amply described by Mr. Greve, whereby the positive potential on a structure is overcome by a sufficient counter electromotive force to make it negative. The effectiveness of the two methods is shown in the paper. The area of its effectiveness can be increased by in-

creasing the distance of the positive ground or the buried anode from the structure. Of course, more energy or a larger anode is required. However, this increased separation may effect other structures passing near or through the two points and may by-pass considerable current. Where it approaches the protected structure the current will leave and cause corrosion of such secondary structures. For this reason it is desirable to limit the separation to some reasonable spacing and increase the number of such protective devices.

It may be possible to bury a wire parallel to the structure in the same trench and to use forced drainage at frequent intervals. If a magnesium

* Union Electric Co., of Missouri, St. Louis, Mo.

wire is installed, bonding at frequent intervals may be sufficient. For this method, aluminum or zinc wire with an electromotive potential against lead of 1.6 and 0.6 volt respectively may be high enough to provide ample protection. Magnesium with a potential of 2.3 volt against lead and 2.5 volt against iron may be too high for the close spacing.

This same method can be used by installing an aluminum wire in an empty duct. This method should be self regulating since when the ducts are dry no current will flow but at the same time no protection is required. When the ducts become wet the current will increase with decreasing resistance at that point where most protection is required.

*By Wiley D. Sanderson**

Mention was made that at several locations cables were installed through cinder-filled areas. It has been the experience of the writer that the only safe location for cinders is far from underground metallic structures. Troublesome corrosion areas on The Detroit Edison Company cable system include one located adjacent to a cinder-banked railroad yard, as well as one under a sidewalk with a cinder foundation. Presumably, these carbon particles percolate through to the cables and set up corrosion cells. Incidentally, cinders in contact with concrete can be very detrimental to the physical condition of the latter.

It is apparent that, after the installation of rectifiers, potentials of up to 0.75 volt were measured within the duct banks. In any case in which sodium chloride (commonly used for street and track de-icing) might

be present, the current involved would produce caustic soda, to the direct detriment of the sheaths. About 0.25 volt negative is as far as we in Detroit wish to carry cable sheaths. Also, is it not possible that other, adjacent, metallic structures might be adversely affected?

Concrete has likewise been a trouble-maker when applied over lead cable sheaths, for fireproofing. The crystalline deposits referred to are lead monoxide and appear in various shades of reds and browns. They are the result of contact of lead with alkalis. Practically all such concrete fireproofing on this cable system has been replaced with silicate-soaked asbestos tape, with very beneficial results.

Mr. Greve should receive the appreciation of operating utility engineers for having pointed out some of the various ways in which our sub-surface structures may be allowed to disintegrate due to corrosion.

* Cable Corrosion and Loading Engineer, The Detroit Edison Co., Detroit, Mich.

Some European Researches on Passivity*

By U. R. Evans*

Introduction

I WOULD FIRST express my appreciation of the honor which you have done me in choosing me as recipient of your NACE Science Award for 1948. This friendly act has brought encouragement to me and those who are working with me; and in the World of today there is nothing more welcome than encouragement. I regret that it is quite impossible for me to be present at your meeting in person. I am hoping that my friend and one-time collaborator, Dr. Mears, to whom I already owe thanks for many kindnesses, will kindly read this little paper for me.

Another valued friend, Dr. Speller, has suggested that I should choose as my topic, Passivity. This is a vast subject, but I can shorten my paper by assuming that the extensive American researches are already known to the audience; I shall, therefore, confine myself to European work, in the hope that I may encourage hearers to study in the library some of the papers quoted. Clearly a second-hand account of any important research, whether it

• In recognition of his many contributions in the field of corrosion research, Dr. U. R. Evans was presented the 1947 Willis Rodney Whitney Award in the Science of Corrosion by the National Association of Corrosion Engineers. Presentation of the award was made during the 1948 Annual Meeting of the Association in St. Louis, Mo. The Willis Rodney Whitney Award was established in 1946 by NACE, and its first recipient was the man who's name it perpetuates.

be obtained from a textbook, from an abstracting journal or from a short survey such as the present one, can be no substitute for direct consultation of the original paper; even in a large textbook the space allotted to the consideration of an important paper may be less than 10 percent of the original length; thus, unless we assume that the paper included matter that was unnecessary, 90 percent of the subject must clearly be lost.

This does not mean that I am pressing anyone to accept lightly either the facts or the interpretation of recorded work. I have a genuine respect for the man who reads and

*A paper presented at the annual meeting of NACE in St. Louis, Mo., April 5-8, 1948.

*Reader in the Service of Metallic Corrosion, Cambridge University, Cambridge, England.

rejects; also for the man who decides to repeat the work before he passes judgement upon it. It is the omission of the library stage in research which is today causing much work to be carried out which would be carried out differently or perhaps not at all, if the investigator possessed a fuller knowledge of what had been already published. If this little communication can do something to impress the importance of studying journals published in all parts of the world, it will not have been written in vain.

Characteristics of Passivity

It is in no way remarkable that a metal should be attacked by one reagent and should resist a second; the fact, however, that, after remaining for some time in that second reagent, it becomes capable of resisting the first (which would normally attack it) represents something which must arouse interest and demand an explanation. Iron, for instance, is violently attacked by dilute nitric acid and remains unaffected by the concentrated acid; however, after exposure to the concentrated acid, it will withstand acid of intermediate concentration which would otherwise attack it.

Heathcote's Demonstration

Heathcote,¹ experimenting in 1907 on the anodic treatment of iron in 16 percent sulfuric acid, demonstrated that "the iron behaves as if one could teach it to become passive." When the current was first turned on, the metal suffered anodic attack, but after an interval it suddenly became passive and the current dropped. When the circuit was broken and re-established, the iron

was once more found to be active, but this time it became passive after a shorter interval than on the first occasion; after the next interruption the time needed for passivation was further shortened. Heathcote noticed also that often a current density which was insufficient to passivate iron which had never been passive before might succeed in restoring passivity to iron which had previously been rendered passive but had become active again.

Evidently passivating treatment confers something on the metal which survives even after the treatment has been discontinued. Not only this, but one specimen can communicate its acquired peculiarities to another. This was shown in experiments described in the letters that passed between Faraday and his Swiss friend, Schoenbein, in 1838²—a correspondence in which the name "passivity" was first used. Schoenbein stated that iron oxidized by heating in air and then introduced into nitric acid of density 1.35 remained unaffected. Unheated iron was violently attacked if introduced without precaution into acid of that strength; but if it was in contact with oxidized iron at the moment of introduction, no attack developed, and the unheated iron remained passive even after it had been separated from the oxidized iron; if taken out and reintroduced in contact with a fresh piece of unheated iron, this latter also escaped attack.

Factors Favorable to Passivity

In the same early work, it was made clear that anodic treatment often promotes passivity while cathodic treatment often restores activity. Schoenbein produced passivity

on unheated iron by anodic treatment in nitric acid by means of an emf provided with a "couronne des tasses." Faraday made the metal alternatively active and passive by bringing it into contact with zinc and platinum below the acid—a procedure equivalent to alternate cathodic and anodic treatment. In the case of iron, passivity is produced with greater difficulty in acid than in alkaline solutions, but the reverse is true of metals like tungsten and molybdenum (which form oxides capable of combining with alkali to form salts, such as tungstates and molybdates). This strongly suggests that passivity is connected with an oxide-film, since the oxides of iron are almost insoluble by dilute alkali but soluble in acid, whereas the converse is true of the oxides of tungsten and molybdenum. The fact that oxidizing agents often produce passivity and reducing agents destroy it also accords with the view that an oxide-film is responsible. The behavior of a chromium anode—at one time considered to be inconsistent with such an explanation—can easily be cleared up. Here the trioxide (CrO_3) is freely soluble. A chromium anode passes readily into solution, provided that the emf applied is sufficient to furnish the considerable energy needed for the formation of the trioxide; if an iodide is present, the iodide ion is discharged at a "lower" degree of anodic polarization* than is needed for the formation of the soluble trioxide, and the anode remains unattacked; for the lower oxides of chromium are sparingly soluble, except in a strongly

acid liquid. Nevertheless, as shown below, other substances besides oxides can play their part in the inception of passivity, which is a somewhat complicated phenomenon.

Stagnant conditions favor passivity, and violent stirring preserves the active condition. If convection in the liquid is carefully avoided, even a feeble anodic current will ultimately produce passivity; the smaller the current, the longer is the time needed for passivation. In moving liquids, there is a critical current density, ω_∞ , below which passivity will *never* set in—however long the anodic treatment is continued; at a higher value (ω), the time of passivation is inversely proportional to $(\omega - \omega_\infty)$ —a simple but important relation, obtained in 1932 by Shutt and Walton⁴ during their studies of the passivity of gold, and confirmed by Armstrong and Butler⁵ two years later.

Breakdown Phenomena

Passivity, whether produced by immersion in an oxidizing solution or by anodic treatment, tends to break down at a place where three phases meet. Such a place may occur at the waterline on a partly immersed specimen, or at the boundary of a drop placed on a horizontal plate. The breakdown is apparently due, in part at least, to the fact that material which at any other point would have been available for the repair of cracking in the protective film, is deposited upon the air-liquid interface instead of on the metal-liquid interface; in many of the author's experiments,⁶ membranous matter has been observed clinging

* I.e. a "less negative" potential, on the sign convention commonly used in America.

to the air-liquid interface at points where the passivity was breaking down.

Bubbles may be formed on a metallic surface if the temperature of water containing dissolved gas is raised or if the pressure is reduced. Wherever a bubble clings to the metal, we have the meeting place of three phases, so that passivity is liable to fail; a water possessing such a composition as to produce no damage on the main part of a steel surface can cause pitting at the sites of the liberated air bubbles—a phenomenon recorded by Eisenstecken,⁷ whose interpretation is, however, different.

Other film-substances besides oxides can confer protection upon metals. The facts that lead-lined vessels can be used as containers for sulfuric acid, that silver can withstand hydrochloric acid, and that magnesium (a metal attacked almost explosively by most acids) will resist hydrofluoric acid (which consumes most metals and even glass) are certainly connected with the sparing solubility of lead sulfate, silver chloride and magnesium fluoride respectively.

Inhibitors

Most salt solutions attack the base metals, such as iron or zinc, in presence of oxygen, provided that soluble anodic and cathodic products are formed when an electric current passes between different parts of the surface. Such currents can arise in different ways. To give an example, electric currents are known to flow on a partly immersed specimen between a cathodic portion at the water-line and an anodic portion lower down. The real existence of these

currents, which are due to differences in oxygen supply, has been demonstrated in the author's laboratory;^{8, 9, 10, 11} their strength has been found sufficient to explain the whole of the corrosion observed. But if either anodic product or cathodic product is sparingly soluble, then there is little attack. The author⁸ found that drops of sodium sulfate, placed on iron, produced much rusting; ferrous sulfate and sodium hydroxide, the two primary products, are freely soluble, although they precipitate the hydroxide mixture, known as rust, where they meet. Drops of zinc sulfate, however, produced far less attack (zinc hydroxide, the cathodic product being sparingly soluble) while sodium phosphate, if sufficiently concentrated, produced practically no change (since iron phosphate, the anodic product, is sparingly soluble). Thus we can distinguish two classes of inhibitors, cathodic inhibitors and anodic inhibitors; the latter are the more efficient but also the more dangerous, since, for electrochemical reasons,¹² they intensify attack if added in insufficient quantity.

Other substances which can precipitate a metal from solution may serve to inhibit corrosion. Thus chromates precipitate ferrous sulfate as a mixture containing the ions Fe^{+++} , Cr^{+++} , OH^+ and under some circumstances CrO_4^{--} or SO_4^{--} . Iron placed in a water containing chromate usually escapes rusting even where the untreated water would cause much rust; the surface film present on iron previously exposed to chromate solution, has been removed by the iodine method; it was found by Hoar and the author¹³ to contain chromium.

Are Oxide Films Dissolved by Acid?

It was at one time objected that the passivity produced by anodic treatment of iron in (say) sulfuric acid cannot be due to an oxide film, since—it was alleged—any oxide film would be at once dissolved by the acid. To test this statement the author¹⁴ carried out some experiments in 1930, using, in the opening stages of the research, the *visible* films produced by heating iron in air so as to develop interference colors; later, having obtained experience with these relatively thick films, he passed on to experiments on thinner, *invisible* films.

Iron heated to give the *early* interference colors, and then placed in dilute sulfuric acid, rapidly lost its color, the films being destroyed. When similar iron, heated to develop second or third-order colors (which require considerably thicker films), was placed in the acid, the films were undermined, and peeled off; when once out of contact with the metal, they were found capable of remaining in the acid for a long period without being destroyed. Finally iron carrying the thinner films (corresponding to the early tints) were found to be unaffected by sulfuric acid containing chromic acid, the colors then remaining undestroyed. This suggested that the destruction of the films in absence of chromic acid is due to the fact that at the cracks in the film, the cell

Iron | Acid | Ferric oxide is set up. The ferric oxide, being the cathode of the local element, is reduced to the ferrous condition, and passes readily into solution; if this reduction is avoided (e.g. through the presence of chromic acid), the ferric oxide films resist dissolution

for long periods. Even in the absence of chromic acid, the ferric oxide films resist dissolution by sulfuric acid for long periods, provided that they are out of contact with the metal; samples of ferric oxide films have been preserved a whole week in normal acid (whether hydrochloric, sulfuric or nitric). It is evidently untrue to assert that an oxide film is in all cases quickly dissolved by an acid.

Experiments were then carried out on a pair of tinted electrodes, clamped to a frame, which were joined by flexible leads to an external battery and were dipped into acid in such a way that current commenced to flow as soon as the two electrodes entered the fluid. The cathode soon lost its colors—confirming the mechanism just suggested—while the anode remained unchanged: the colors were preserved and the iron received protection against attack—practically all the current passing being devoted to the evolution of oxygen. If the circuit was interrupted for more than a few seconds, the colors disappeared and, when the connection was restored, the anode was found to be active, so that the iron passed into solution without evolution of oxygen. However, an interruption of a second or two could be tolerated without destruction of the colors, and, if current was restored within this time, the evolution of oxygen was at once resumed—without appreciable attack on the metal; the power of the iron anode to survive this short interruption without destruction of the films or loss of passivity can be attributed to a charge of excess oxygen which had already accumulated in the metal and which

served to prevent the "reductive dissolution" mentioned above; there was evidence that such a charge existed, since bubbles of oxygen continued to develop on the anode surface for a second or so after the interruption of the circuit. If the current-flow was restored at the "critical instant" when the film had been destroyed on part of the surface but not on the rest, then the undestroyed part of the film, undermined by the anodic attack from the area where the film had disappeared, peeled off and fell to the bottom of the containing vessel. When once the film-fragments were out of contact with the metal, they could remain in the acid for a long period without apparent change.

It was now possible to carry out analogous experiments on untinted specimens (i.e. specimens of iron which had *not* been heated in air after abrasion). These were found to be active when first the current was turned on, and iron started to pass into the acid solution as ferrous sulfate. If the current density was high, passivity set in after short delay, and anodic attack then practically ceased, since the current was now devoted mainly to the evolution of oxygen. After some time, it was found possible to interrupt the current for a short period without loss of passivity, but if the interruption was too long, passivity disappeared, and when the connection was re-established, anode attack on the iron started once more. When experience had been gained, it was found possible to estimate the interval needed for the loss of passivity at some, but not all, parts of the anode. In this way it was possible to isolate the

protective film by undermining it; the film was thinner than those capable of conferring interference tints, and, when once out of contact with the metal, it could be preserved in the acid for a considerable time without destruction. The film had been invisible while in optical contact with the metal, but became visible when it was removed from the bright reflecting basis. These experiments showed that anodic treatment in acid could lead to the production of a ferric oxide film, which was capable of resisting the acid solution, provided that reduction to the ferrous state was prevented. It was felt that the results disposed of the criticisms quoted above.

The rapid "reductive dissolution" of ferric oxide by acid, and the much slower "direct dissolution," are at present being studied by Pryor in the author's laboratory.

Electrochemical Studies of Film-Growth

The remarkable series of researches carried out at Vienna by W. J. Müller and numerous collaborators,¹⁵ of whom W. Machu deserves special mention, has placed the phenomenon of anodic passivation on a quantitative basis. Under stagnant conditions, the variations of current with time were found to obey two equations, which can be obtained theoretically—without *ad hoc* assumptions—by combining the established laws of electrochemistry; one equation represents the lateral spreading of a film and the other the thickening of a film. The obedience to these equations leaves no reasonable doubt that, in the numerous cases studied, a solid appears at

certain points on the anode and spreads out sideways over the anodic surface until nearly the whole is covered, after which the film commences to increase in thickness.

Müller found it possible to calculate from the electrical measurements the electrical conductivity of the liquid which still continues to fill the pores in the solid layer. He discovered that, where electrolysis had commenced in sulfuric acid, the liquid next to the iron anode possessed the conductivity of a saturated solution of the ferrous sulfate. This suggested that the solid thrown out was ferrous sulfate itself—a suggestion confirmed by studies with the polarizing microscope. If the sulfuric acid had been saturated with ferrous sulfate before the experiment, the falling off of current with time commenced after a shorter delay, so that the period needed to render the iron passive was shortened also. But the solubility of the salt in question is all-important in deciding the time of passivation. A lead anode in sulfuric acid becomes passive much more quickly than an iron anode; the passivation of lead obeys the same two equations as that of iron, although the time required is much shorter; on lead the whole process is over in a fraction of the second, while, in the case of iron, it occupies many minutes.

But although the deposition of ferrous sulfate on an iron anode is responsible for the falling off of current with time, it cannot account for the change in properties of the metal, which persists after the current has been turned off (the change may not last long in acid solution but it is more permanent in neutral solution).

It should be noticed that, although the deposition of (say) solid sulfate reduces the total current flowing, the current density at the sub-microscopic gaps between the crystals, where the iron is still exposed, steadily increases, ultimately reaching such fantastic values as 50 to 100 amps/cm². At this stage, the necessary supply of iron atoms in a suitable condition to pass into solution as ions may fail, and other reactions—which energy considerations would preclude at low current densities—begin to take a share in the task of providing for the current. These may include the discharge of (OH)' ions to give oxide or even oxygen; when an oxide film appears on the metal, it will further hinder the passage into the state of metallic cations, and ultimately nearly the whole of the current is devoted to the production of oxygen as opposed to attack on the metal. The oxygen-evolution, of course, stirs up the liquid, and the crystals of ferrous sulfate dissolve or are dispersed, so that the surface—which often becomes clouded during the onset of passivity—once more resumes its bright appearances.

It might perhaps be expected that, when fresh acid has again reached the surface, the metal would revert to the active state. However, as explained above, the *direct* dissolution of an oxide film in acid does not take place, and *reductive* dissolution is prevented by the anodic current—provided that the current density is sufficiently high. At relatively low current densities, however, passivity may disappear after a time; when activity reappears, the current automatically increases, leading, in due

course, to the reappearance of passivity. Thus we experience, under suitable conditions, a "periodicity" or alternation between the active and passive conditions—an interesting phenomenon described at length in the papers of Hedges.¹⁶

The work of Hickling¹⁷ on the anodic behavior of platinum and gold (based on the use of a cathode-ray oscillograph) appears at first sight to present a contrast with the experiments described above. On gold, Hickling showed that after the formation of a unimolecular layer of Au_2O_3 the potential reached a value at which most of the current was devoted to the evolution of oxygen. Hickling adds, however, that "further anodic polarization may, of course, increase the thickness of the oxide layer." There is no reason to think that the circumstances are seriously different on an iron anode. Probably after a unimolecular film has covered the whole layer, the *greater part* of the current will be expended on the liberation of oxygen gas, but that the film will continue slowly to increase in thickness. Nor is a slow passage of iron into the liquid impossible. In an early paper, Lobry de Bruyn¹⁸ expressed the view that, after passivity has been definitely established, the greater part of the current is used up in the liberation of oxygen; but that a small portion is still devoted to attack on the iron.

Optical Studies of Film Growth

Any doubt that the films can reach thicknesses of several molecular diameters was dispelled by the work of Tronstad¹⁹ at Trondheim, Norway, who developed a method, based

on the use of polarized light, for measuring the thickness of a film present on a smooth metallic surface; the method also gave some information regarding the refractive index of the film-substance. Iron specimens were alternately subjected to anodic and cathodic action for periods of 30 minutes. During the first anodic period a film about 30 angstroms thick was built up on the surface; the refractive index was about 3.0, which was considered to show that film consisted of anhydrous oxide. During the succeeding cathodic period, the film became thinner but did not disappear completely. During the second anodic period a greater thickness was obtained than during the first one and thus, by alternate anodic and cathodic treatment, films were built up until the optical method indicated a thickness of nearly 100 angstroms (one-millionth part of a centimeter); such films should show interference colors when viewed at grazing incidence, and this was actually confirmed by observation. During the anodic and cathodic periods, the potential was found to move up and down, being noble when the film was thickening and base when it became thinner.

Films Produced on Mirror-like Surfaces

Tronstad's films were produced on mirror-like surfaces. Greater thicknesses would almost certainly be reached on a rough surface. Incidentally, the building up of thickness by alternate anodic and cathodic treatment is analogous to the formation of active material on a lead accumulator plate.

Effect of Discontinuous Oxide Films

No serious person who has read the literature can doubt that, in the cases considered above, passivation is "connected with" the formation of a film. To say that passivation is "caused" by a film may be misleading, if the words are taken to imply that; whereas passive metal carries a film, active metal is free from one. Actually any metal (except perhaps gold and certain metals of the platinum group) develops an invisible film if exposed to air at ordinary temperature. This has been demonstrated by several independent methods; gravimetrically by Vernon, Akero and Stroud,²⁰ electrometrically by Miley and the author²¹ and optically by Winterbottom,²² using a development of Tronstad's method; all methods show that the oxidation commences rapidly, but becomes very slow while the thickness is still small. The formation of these *invisible* films on metals exposed to fairly pure air at ordinary temperatures obeys a different growth law from that governing the formation of the *visible* films at high temperatures (or even at ordinary temperatures if sulfur compounds are present). The growth of the visible films is generally believed to be connected with movement of metallic ions and electrons outwards through the oxide or sulfide film, and this belief is confirmed by the good agreement between the values of the growth-constants obtained experimentally with those calculated from the electrical data—as shown by the numbers which Price²³ has collected from the papers of Wagner. On the other hand, the growth of invisible films is believed

by the author²⁴ to be a "crack-heal" process; the films keep breaking down under the compressional strains present (strains demonstrated by the wrinkling or curling of the films transferred from the metal²⁵ to vaseline-covered glass) and fresh oxide is formed at each point of breakdown. If this view is right, it at once becomes obvious why the films fail to provide appreciable protection against water or salt solutions, unless some inhibitor is present to repair the cracks as they appear. In waters containing chloride, the amount of inhibitor needed is particularly high.

It should not, however, be concluded that these discontinuous, ever-cracking films formed by exposure to air play no part in passivation. Iron which has been abraded and exposed to air for a long period, fails to precipitate copper when brought into contact with copper nitrate solution of a composition which rapidly deposits copper from freshly abraded iron. But the passivity must be ascribed in part to the oxidizing power of the nitrate, since if copper sulfate be used, copper deposition usually occurs, starting often after a few seconds delay at isolated points and then a spreading out over the whole surface.

The decision as to whether a specimen shall be attacked or shall remain passive may be influenced both by its past history and by the composition of the liquid in which it is placed. Past history only exerts an important influence, if the liquid chosen lies on the borderline between a passivating or activating solution. Mears and the author²⁶ carried out statistical experiments on

drops of sodium bicarbonate solution placed on iron. Dilute solutions always produced rusting, and concentrated solutions always left the iron passive, probably because the solubility of iron carbonate or bicarbonate (the anodic product under consideration) will be depressed by excess of $(\text{HCO}_3)_-$ ions. Intermediate concentrations (0.07 M under the conditions observed) caused rusting below some drops but not below others, the proportions varying with the previous history of the metal. Iron exposed to air for only 15 seconds before the drops were applied developed rust below 84 percent of the drops; but the proportion steadily fell with the time of air-exposure, and, after 1024 minutes, only 27 percent suffered rusting.

Another interesting effect of the film produced by air-exposure was studied by Hoar¹³, during his estimations of the chromium-contents of films taken from the surface of iron which had been immersed in potassium chromate solution. If the surface had been abraded *just before* immersion the film contained about 5×10^{-8} gram/cm² (as Cr_2O_3), whereas if the surface was exposed to air for 24 hours before immersion, the content was only 1×10^{-8} gram/cm², evidently because the gaps in the invisible film which required repair with the ferric-chromic mixture had become less numerous after that long air-exposure. If the chromate-solution contained a trace of chloride, the value for the Cr_2O_3 per unit area became considerably higher, and the film was much thicker, since interference colors could be seen (at still higher chloride contents, rust appeared). These results are not

easy to reconcile with the ideas that passivity in chromates is due to a monomolecular film of attached $(\text{CrO}_4)^{--}$ ions or a layer of oxygen molecules. Another later set of observations, due to Thornhill, also suggest that the passivation is a *slow* process (not a rapid process such as adsorption). Thornhill, using a sensitive photo-electric method for determining iron, found that during the first hour of immersion the rate of attack by Cambridge water containing chromate, although appreciably less than that of the untreated water, was of the same order of magnitude. Protection slowly developed, and after eight hours, the corrosion-rate in the chromate-containing water had become very slow, while that in the untreated water was still rapid. Thornhill's results are shortly to be published.

A striking case of the effect of air-exposure occurred in Müller's work¹⁵ on anodic passivity. An iron anode carrying an invisible film (produced by air-exposure) became passive in about 0.01 seconds, whereas a similar specimen nearly free from oxide at the outset required 20,000 times as long, under otherwise similar conditions. In the first case, the anodic treatment had merely to repair any cracks present or forming in the film; in the second, it was necessary to build up a film over an initially bare surface.

Another example of the same principle (although the word "passivity" has not generally been applied to it) may be quoted from Vernon's²⁴ extensive work on atmospheric corrosion. Iron specimens exposed to indoor air but shielded by muslin screen from dust particles re-

mained free from rust, whereas unscreened specimens developed rust-spots at points where dust-particles (probably possessing a hygroscopic or acid character) had settled on the surface. A piece of iron, after eleven months exposure behind muslin, was withdrawn and exposed to ordinary dusty air; it suffered much less change than a freshly cleaned specimen, preserving its bright appearance and showing a smaller gain in weight; this was clearly due to an invisible oxide film built up during the eleven months of "sheltered existence."

Part Played by the Metal

An unguarded statement that "passivity is caused by films" tends to conceal the part played by the metal in deciding whether or no a film of the required character can be produced. Consider two similar electrolytic cells containing the same solution, one provided with a zinc anode and the other with an iron anode of the same size; suppose them to be arranged in series so that the same electric current flows through both. The zinc anode appears capable of providing an almost inexhaustible supply of cations, so that even at very high current densities it will continue to pass into solution at a potential not very different from the equilibrium value. This is not true of the iron anode, which shows considerable "polarization," that is to say, the potential has to move far from the equilibrium value if the current is to flow; the divergence increases as the current density is raised. Evidently alternative reactions leading to oxy-

gen or oxide films will become possible in the case of the iron anode at a current density at which the zinc anode is still capable of furnishing ions at the required rate. It is not unreasonable to argue that the passivity must be primarily attributed to the failure of the iron to provide ions at the required rate at a potential where alternative reactions are impossible: if so, we must relate passivity to the "polarizability" of the metal. But the fact that the changes in the chemical and electrochemical properties of the iron remain even after the current is turned off must be ascribed to the formation of a film—and also, in some cases, to the charge of oxygen which serves to prevent its reductive dissolution.

Suggested Sources on Subject

The fact that passivation is closely bound up with polarizability suggests that many papers describing electrochemical researches may help in our understanding of passivation even if the word passivity does not always appear in the titles. It would be impossible to mention all the European laboratories at present conducting electrochemical research—which often reaches a high scientific standard, despite the difficulties of the economic situation; but attention should be directed to any papers which may appear during the years to come from the laboratories of Pourbaix at Brussels, Chaudron at Paris, Masing at Göttingen, Feitknecht at Bern, Heyrovsky at Prague, Akimov at Moscow, Piontelli at Milan and Ruis at Madrid.

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Plastic Coatings and Corrosion*

By C. G. Munger*

PLASTIC COATINGS in recent years have been becoming more and more important in their relationship to the prevention of corrosion. By plastic coatings is meant only those materials which contain purely plastic materials and not those paints and coatings which are made up of oil, varnishes, natural resins and synthetic varnish resins such as the alkyds. These are important in their particular fields, however, they are comparatively old products and have been studied for years. Most plastic resins are comparatively new, having been developed within the last fifteen years. While it is true that nitrocellulose coatings or lacquers and baked phenolic coatings have been known many years these should be included in the plastic coating series since they are actually plastic materials.

Materials which are most important in the plastic coating line include the polyvinyl chloride acetate resins, chlorinated rubber, methacrylates, pliolite, Saran, Geon and many similar materials. The definition of a plastic coating, is, then, a solution of purely plastic resins modified by plasticizers and pig-

ments which on the evaporation of the solvent leaves a film with the same properties as the original synthetic resin from which it is made. So far the large use of plastic coatings has been in the chemical field where such special properties as they possess could be best used. They have been used as a lining for chemical tanks, including acids, alkalis, salts of many sorts, as a coating to resist hydrogen sulfide corrosion, in the petroleum and sewage fields, as a coating for the interior of food containers such as wines, soy sauce, medicinal water, sugar and corn syrup tanks, a coating for airplane battery cases and as a coating for underground tanks used for storage of diesel oil and aviation gasoline. As a marine coating they have been used to protect the exterior of steel vessels from corrosion, as an interior tank coating for salt water ballast, fresh water, and as an interior lining for gasoline tanks.

All of these problems involve severe corrosion and each requires a specific set of properties for the coating to withstand all of the requirements that are demanded. Considering the many different uses where plastic coatings have been effective there are four factors essential to any coating which is to withstand such specialized and severe

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corrosive conditions. The first is the selection of a plastic which has the basic chemical properties to resist the corrosive conditions involved. The second is the formulation of this basic material for maximum impenetrability both to the chemical involved and to moisture vapor. The third is high adhesion over the basic surface. The fourth is the application of the finished coating in a proper thickness and to a properly prepared surface. It is felt that unless these four factors are all considered the coating will not be effective.

Going back to Item 1, materials; there is at the present time a wide range of plastic materials from which coatings can be made, each with different properties. The most important group and the one which has received the most publicity is that of the vinyl resins. In this group we have the Vinylite resins which are poly-vinyl-chloride-acetate-copolymers, the Geon resins which are the vinyl-chloride, and vinyl-chloride-vinylidene-chloride copolymers, the Seran resins which are vinylidene-chloride and acrylonitrile-chloride-copolymers, and the new Marvinol resins which are poly-vinyl-chloride. These materials have many properties in common. They provide tough, elastomeric films, have a high resistance to acids, alkalis and chemical solutions in general, a high resistance to oxidizing conditions and age, they have a limited solvent solubility, excellent weather resistance when properly pigmented and in general good physical properties as far as coatings are concerned. They have another important property in common which

creates a problem in coating formulation and that is limited adhesion.

The second type of material is the styrene group of resins. Styrene, itself, while it has been extensively used as a plastic material for a number of years because of its clarity, easy molding and processing, has not been formulated into a satisfactory coating. It is characterized by an almost zero water absorption, is unaffected by aqueous solutions of salts, acids, and alkalis, is soluble in coal tar hydrocarbon, chlorinated hydrocarbon and esters. As formulated into a coating, however, it loses many of its good properties, having a very high moisture vapor transfer rate with a tendency to craze on drying and aging. This is not particularly true, however, of some of the newer styrene copolymers with such materials as butadiene. One of these, of course, is the familiar GRS synthetic rubber. However, this is only one of the copolymers which can be formed. Some of the newer materials have good film properties, good chemical resistance, good adhesion.

Chlorinated rubber is the third type of synthetic resin which has had extensive use in coatings. Chlorinated rubber has good chemical resistance, is unaffected by most acids, alkalis and salt solutions. It has low moisture absorption, is odorless, tasteless, and non toxic and non inflammable. It also has some definite limitations. High temperatures cause it to decompose easily, it is either softened or soluble in animal and vegetable oils and fats, it is not resistant to most organic acids. The film it forms is hard, tough, and has good physical properties.

The acrylic resins provide another type of coatings. The acrylic series include such materials as polymethyl-methacrylate, polymers of ethyl acrylate, normal butyl methacrylate, etc. The hardest of these resins is methyl-methacrylate; softer more flexible films are provided by polymers such as normal butyl methacrylate. These coatings have good chemical resistance, good film properties, however, their use has been limited mainly to decorative coatings and to clear coatings for such materials as silver, chromium, brass and similar materials. They have excellent electrical properties and have been used for insulating varnishes.

The cellulose group of synthetic resins, including cellulose nitrate, cellulose acetate, cellulose-aceto-butyrate, and ethyl cellulose, has been extensively used in coatings. These materials are generally known through their use as lacquers, such as automobile finishes, fast drying coatings for fast production items such as toys, household utensils of all types, and as furniture finishes. The properties of these various materials, while not the same, are very similar and vary many times only in degrees. They provide tough films, have good weather resistance, comparatively low water absorption and in the case of ethyl cellulose, a high resistance to alkalis.

Another group of coating materials, and it is probably the oldest synthetic resin used for coatings, is the unmodified phenolic baking coating. This material was originally used as a tarnish proof coating for brass bedsteads. Because of its good properties, however, especially its re-

sistance to water, foods, and mild acid solutions, coatings formulated with the unmodified phenolic resins have been extensively used to prevent corrosion and contamination to tanks, process equipment, pipelines, processing of many foods, beverages, and sour crude oil. It has been possible to replace many special steel or nickel corrosion-resistant alloys in industrial use by coating iron or steel with these phenolic resin baking finishes. Resistance of these materials to alkalis, however, is very poor. This is the large limiting factor to the use of these materials.

There are also some new synthetic resins which have been incorporated into coatings. One of these is the silicone type resin. This material has been rather highly publicized by the bouncing putty; however, there are several silicone polymers which have excellent coating properties; and properties which are not available in any other materials. The outstanding quality is that of heat resistance. They are also characterized by high electrical resistance, excellent water resistance, and resistance to weathering. It is possible to formulate coatings from these materials which will withstand 500-600° F. almost indefinitely and temperatures as high as 1000° F. for several hours. Chemical properties are good although not outstanding. Combining good chemical resistance with weathering resistance and high temperature stability, the coatings composed of these materials provide excellent protection to stacks and furnace breechings where high temperatures provide difficult corrosive areas.

Another high temperature mate-

rial recently developed is Teflon. This is poly-tetrafluor-ethane and as far as chemical and physical properties are concerned, this material is outstanding for its resistance to heat and extreme chemical exposure. Molten alkali metals, such as sodium, appear to be the only materials which have any appreciable effect on it. Because of this high resistance to chemicals, however, its value as a coating material is almost lost. There is no known way of processing it into a solution or even a hot melt so that it can be formed into a coating. The only processing method so far which has met with any success at all is that of flame spraying the material onto a surface. The difficulties here are processing a highly heat-resistant material into a continuous film over a large area by flame spray has not been fully overcome.

Another of the newer materials is that of polyethylene which like Teflon has very excellent properties, however, again due to its low solubility in common solvents, satisfactory coatings have not been obtained. It is more easily processed than Teflon in that it is compatible with paraffin wax and may be easily formed into a melt with combinations of paraffin. Chemical and water resistance is excellent, however, because of its limited solubility its use in the coating field has been very limited.

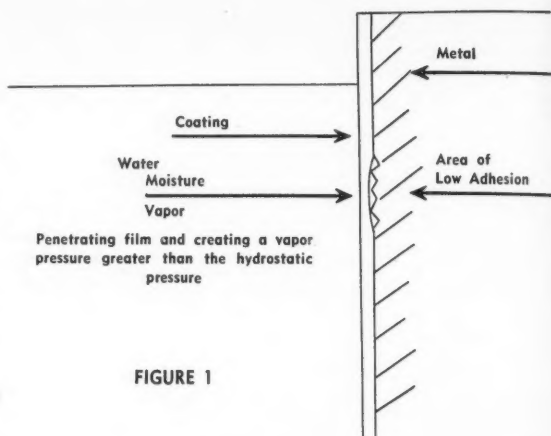


FIGURE 1

During the past fifteen years in the extensive work done by the author's company in the formulation of plastic coatings, the properties of one group of plastics have been outstanding. This group is the vinyl chloride and vinyl chloride copolymer group of resins. The properties of these materials in the formulation of coatings is outstanding. They provide films with excellent physical properties, hardness, toughness, and high tensile strength. The chemical resistance of these resins is outstanding. They are unaffected by mineral acids with the exception of concentrated sulfuric. They are unaffected by concentrated solutions of caustic soda, temperatures as high as 230-250° F. They are unaffected by salt solutions such as ammonium nitrate, sodium chloride, magnesium and calcium chloride, ferric chloride, copper sulfate and similar materials. Moisture absorption is low, moisture vapor transfer is low, they are odorless, tasteless, non toxic, non flammable.

Starting with a material of the above chemical and physical proper-

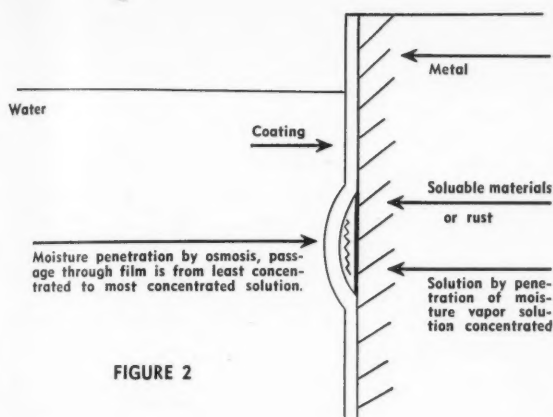


FIGURE 2

ties, the second factor of a successful corrosion-resistant coating enters, that is the factor of proper formulation for specific chemical or corrosion resistance and resistance to moisture and moisture vapor transfer. It is believed that the factor of impermeability and high moisture vapor transfer resistance is of the utmost importance in a corrosion-resistant coating. The quality of impenetrability by chemicals is obvious. Resistance to moisture vapor transmission, however, is somewhat more subtle. It is the general consensus that distilled water is one of the most difficult materials for a coating to resist. Blistering, loss of adhesion, penetration of the coating by water are the most obvious types of failure.

It is believed that moisture can cause the failure of a synthetic resin coating by three means. The first is by direct moisture-vapor transmission into an area under the coating where the adhesion is poor, or into a porous spot, pore or void in the material over which the coating has

been applied. In either case it is possible for the moisture vapor to pass through the coating, set up a vapor pressure in the area which is conceivably greater than the hydrostatic pressure of the liquid on the outside of the coating. In such a case blisters would form with no appreciable water or liquid in them. Such blisters have been

encountered many times in actual applications (see Figure 1).

The second type of failure is believed caused by osmosis. Osmosis can be defined as the passage of water through a semi-permeable membrane from a solution of lesser concentration to a solution of higher concentration. For example, assume a water tank which has been painted. The coating has been applied over some rust. In this case the coating is a semi-permeable membrane and the first reaction is that of moisture-vapor passing through the film and being absorbed by the rust or other soluble material on the coated surface (example, sweat from handling with bare hands). In so doing the rust has a slight tendency to hydrolyze and go into solution as ferrous hydroxide and in so doing creates a solution with a higher concentration of solutes in solution than the water on the exterior of the film contains. Therefore the osmotic pressure of the ferrous hydroxide solution under the film is considerably higher than the osmotic pressure of the water on

the exterior of the film. In such a system water passes through the semi-permeable membrane in the direction of the more concentrated solution or the solution with the higher osmotic pressure (see Figure 2).

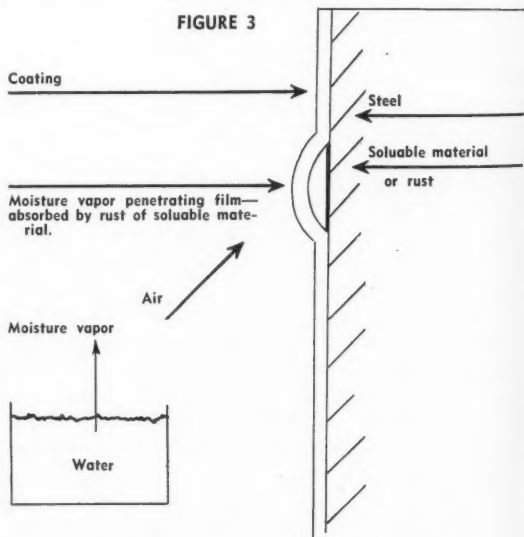
As the water passes through the film, blisters form and eventually can rupture allowing free access of the water to the metal. Actually such a reaction can take place through the action of moisture vapor alone as is shown in the attached diagram. This can account for considerable blistering and coating failure even where the coating is not subject to continual immersion. Absorption of moisture vapor through the coating film causes much of the rust growth underneath paints which is characteristic of areas of high humidity (see Figure 3).

The third type of failure where moisture is a factor is that caused by electroendosmosis. Electroendosmosis can be defined as the passage of liquid through a membrane under the force of an applied electric current. The direction of the migration of water through the membrane is toward the pole which has the same sign as is possessed by the membrane. Using this definition and the fact that an electric potential is set up between coated and uncoated areas of the same metal surface, the possibility of an electroendosmotic ef-

fect can easily be seen. A. C. Elm, Research Division, Technical Department, New Jersey Zinc Company, in his article, *Paints as Moisture Barriers*, states that the direction of the moisture or water can be either toward the anode or the cathode depending upon the charge on the paint film. It has been their experience that most of the paint films that they have examined carried negative charges, therefore the movement of the water through the film was toward the cathode (see Figure 4).

Using this concept, it is easy to understand the blistered areas which many times form around a spot of corrosion under a coating.

It can be seen from these three effects, all of which are caused by moisture in one form or another, that the formulation of a coating to resist severe corrosive influences must be formulated as well for a



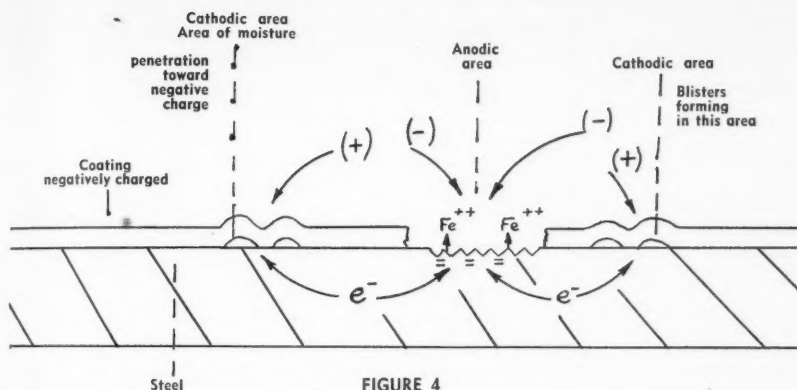


FIGURE 4

minimum of moisture-vapor transmission. This can be accomplished, assuming a basically chemical moisture resistant material such as vinyl chloride plastic, by the use of hydrophobic pigments, highly water resistant plasticizers and the use of plate type pigments which form a shingle effect in the film when dry. Such pigments are aluminum flake, mica, talc and a newer material, stainless steel flake.

The effect of the three above forces on coatings has been demonstrated many times in the use of plastic coatings for resistance to chemicals. As an example, vinyl chloride coatings have been developed for caustic soda storage tanks. Caustic does not affect the vinyl chloride; however, the efficiency of the coating goes up directly as the concentration of the caustic solution. A dilute solution will cause blisters and coating failure at a much lower temperature than concentrated solutions. At 70 percent concentrations the coating is unaffected by continuous immersion at 230° F.

The third factor mentioned, adhesion, is obvious since without adhe-

sion the coating would be wholly ineffective against either physical or chemical forces.

The last factor which is believed to be essential for corrosion-resistant coatings is that of application and surface preparation. While this may be true with all coatings, it is believed especially true for synthetic resin plastic coatings since these materials are used for resistance to extreme corrosion and where extreme chemical resistance is a factor. There are two factors in preparation of the surface. The first is to make sure that the surface is free from all foreign material such as dirt, grease, rust and scale. The second is that of increasing surface area by breaking up the surface so as to provide increased mechanical adhesion.

Following is a list of methods of surface preparation by decreasing effectiveness: sandblasting, pickling, flame treatment, chip and wire brush.

Application of the coating after the preparation of the surface is of equal importance. The first is the application of multiple coats. This

provides for appreciable film thickness, reduces to a minimum the possibility of pinholes, holidays and missed areas, and tends to equalize hills and valleys in the surface over which the coating is to be applied. Multiple coats are most important in plastic coatings because of low solubility of the basic materials the non-volatile content of the basic solutions is low. A second factor which is related to the multiple coats is that of varying the color between coats. While this is not essential it materially aids in obtaining full coverage of every coat and helps reduce the possibility of pinholes and holidays.

A third factor in the application is to make sure that once applied the coating is thoroughly dry. The solvents in the formulation are often the most reactive and least chemical resistant elements in the plastic coating and unless they are completely removed, can in the case of a coating used for chemical exposure, cause the breakdown of the coating.

The use of plastic coatings formulated with specific chemical resistance, high resistance to moisture vapor transmission, excellent adhesion and properly applied is extremely wide. Following are some examples in the use of vinyl coatings in a number of widely different fields.

In the last few years sour crude oil has created extensive corrosion problems which extend from the bottom of the well up through the well tubing into the field tanks, from the field tanks through the pipelines to pumping stations, from the pumping stations into the refineries. Plastic coatings have materially reduced

this corrosion problem. They have been applied both as the phenolic baking coating on the interior and exterior of drill stems and well tubing and as vinyl resin coatings for the same purpose and including the coating of lease tanks, pumping lines, storage tanks and pumping stations and the run-down tanks after primary distillation in the refinery. As an example of the effectiveness in this case: in 1946 a well in West Texas was pulled 36 times because of tube failure. The tubing in this well was coated with vinyl plastic coatings in July, 1947, and to the best of our present knowledge is still in production. The main corrosive elements in sour crude production are hydrogen sulfide and salt water.

Another example of the use of synthetic resin coatings is in sewers and sewage treatment plants where both concrete and steel are seriously affected by hydrogen sulfide corrosion. In this case, because of the multiple factors involved where sewage is concerned, that is resistance to molds, bacteria, high resistance to water, resistance to animal and vegetable fats and oils, soaps, greases, resistance to petroleum products, high resistance to the action of hydrogen sulfide gas, the vinyl resin coatings were selected after exhaustive tests in some of the worst areas in the United States. Vinyl resin coatings have since been applied to concrete pipelines, wet wells, pumping chambers, manholes, clarifiers, and similar sewage equipment.

Water provides a tough corrosion problem, however, it is believed that the coating of drum gates, such as used on Grand Coulee, Friant and

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Shasta dams provide one of the toughest water corrosion problems. In this case the drum gates operate between piers. These piers have a milled steel surface on which a steel water seal from the drum gates operates. The problem is to prevent corrosion of the pier plate when subject to full immersion as well as when the drum gate is in its low position and the pier plate is subject to alternate wet and dry conditions and weather.

Vinyl resin coatings were selected for this work because of their toughness and resistance to abrasion and excellent adhesion as well as their high resistance to water. The vinyl resin system applied to the pier plate at Grand Coulee Dam has been in service for over five years without appreciable failure of the coating system.

In the chemical field synthetic resin systems have been most extensively used. Here they have been

used in coatings for such difficult exposures as ammonium nitrate storage tanks, coating for the interior of commercial hydrochloric acid storage tanks, a coating for caustic soda storage tanks with a 70 per cent concentration of caustic at 230° F., a coating for formaldehyde storage tanks, alcohol storage tanks, tannic acid tanks, molasses storage tanks, and many similar exposures.

In many cases there are records of vinyl coated storage tanks which have prevented both corrosion to the container and contamination to the contained liquid for periods of several years without sign of failure. It is believed therefore, that plastic coatings are providing a major tool for the prevention of corrosion in the major industries at the present time. Because they can be effectively specifically formulated, their effectiveness should increase materially over the next few years.

STATEMENT OF THE OWNERSHIP, MANAGEMENT, CIRCULATION, ETC., REQUIRED BY THE ACT OF CONGRESS OF AUGUST 24, 1912, AS AMENDED BY THE ACTS OF MARCH 3, 1933, AND JULY 2, 1946, Of Corrosion, published monthly at Houston, Texas, for October 1, 1948.

State of Texas, County of Harris, ss:

Before me, a Notary Public in and for the State and County aforesaid, personally appeared A. B. Campbell, who, having been duly sworn according to law, deposes and says that he is the Executive Secretary of Corrosion and that the following is, to the best of his knowledge and belief, a true statement of the ownership, management (and if a daily, weekly, semiweekly or triweekly newspaper, the circulation), etc., of the aforesaid publication for the date shown in the above caption, required by the Act of August 24, 1912, as amended by the Acts of March 3, 1933, and July 2, 1946, Section 537, Postal Laws and Regulations, printed on the reverse of this form, to wit:

1. That the names and addresses of the publisher, editor, managing editor, and business managers are: Publisher, National Association of Corrosion Engineers, 711 Main St., Houston, Texas; Editor, Dr. Irv. M. Parker, Box 266, Bremen, Ga.; Managing Editor, W. M. Wernett, 905 Southern Standard Bldg., 711 Main St., Houston, Texas; Executive Secretary, A. B. Campbell, 711 Main St., Houston, Texas.

2. That the owner is: (If owned by a corporation, its name and address must be stated and also immediately thereunder the names and addresses of stockholders owning or holding 1 percent or more of total amount of stock.)

The National Association of Corrosion Engineers, Houston, Texas. A non-profit organization, therefore no stock issued.

3. That the known bondholders, mortgages, and other

security holders owning or holding 1 percent or more of total amount of bonds, mortgages, or other securities are: None.

4. That the two paragraphs next above, giving the names of the owners, stockholders and security holders, if any, contain not only the list of stockholders and security holders as they appear upon the books of the company but also, in cases where the stockholder or security holder appears upon the books of the company as trustee or in any other fiduciary relation, the name of the person or corporation for whom such trustee is acting is given; also that the said two paragraphs contain statements embracing affiant's full knowledge and belief as to the circumstances and conditions under which stockholders and security holders who do not appear upon the books of the company as trustees, hold stock and security in a capacity other than that of a bona fide owner; and this affiant has no reason to believe that any other person, association or corporation has any interest direct or indirect in the said stock, bonds, or other securities than as so stated by him.

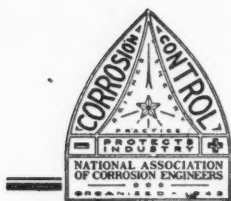
5. That the average number of copies of each issue of this publication sold or distributed, through the mails or otherwise, to paid subscribers during the twelve months preceding the date shown above is (This information is required from daily, weekly, semiweekly, and triweekly newspapers only.)

A. B. CAMPBELL, Executive Secretary.

Sworn to and subscribed before me this 24th day of September, 1948.

MORRIS K. WOMACK.

(Seal) Notary Public in and for Harris County, Texas.



Topic of the Month

CORROSION IN THE POWER INDUSTRY

Irwin C. Dietze*

ONE OF THE IMPORTANT corrosion problems which is always confronting the electric power industry is that of replacing corroded condenser tubes.

In Southern California the Department of Water and Power of the City of Los Angeles, the Southern California Edison Company, both have steam power plants which utilize sea water for cooling. The sea water in the Los Angeles harbor and vicinity is contaminated with sewage and industrial wastes which cause a special corrosion problem on the condenser tubes and other equipment in contact with sea water. Condenser tubes which have a fairly long life in other sea-shore cooling equipment only last a few months.

The Department of Water and Power has been making a special study of this corrosion problem, and in the steam unit put into service last year and other units now under construction, a large number of different alloy tubes have been installed to test their resistance to corrosion in this water.

Recently a small group of tubes was treated by spraying the inside

with three coats of a plastic paint and baking under vacuum. After 8,000 hours of operation some of the tubes were removed and found to have no sign of corrosion, and the plastic coating was still in good condition. The life of the tubes without the plastic paint was about six or eight months. The heat transfer decreased when the tubes were first put into service but after ten days was as good or better than the original uncoated tubes. This plastic coating seems to be so successful that a batch of 500 tubes will be plastic coated so that they can be tried under varied conditions.

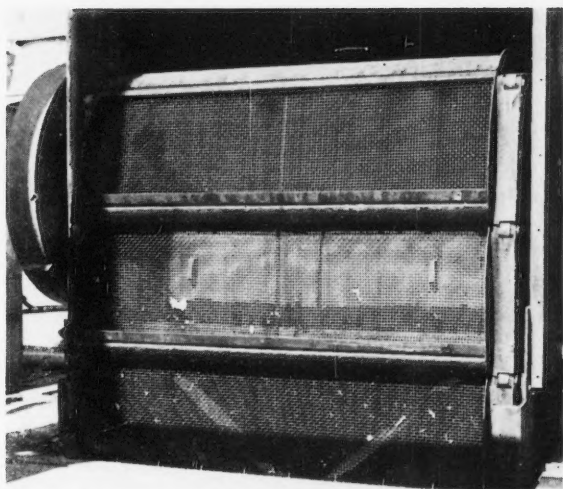
In another case the same plastic paint was sprayed on the inside of a bronze circulating pump which had become corroded and eroded from sea water. The plastic paint not only stopped the erosion but increased the flow about 2 percent or 500 gallons per minute over the original capacity of the pump. After one year of service the slick glassy surface of the plastic coating is still in good condition.

Another type of plastic paint was applied to trays attached to bronze revolving screens which remove trash from the sea water before it

* Electrolysis Engineer, Department of Water and Power of the City of Los Angeles.

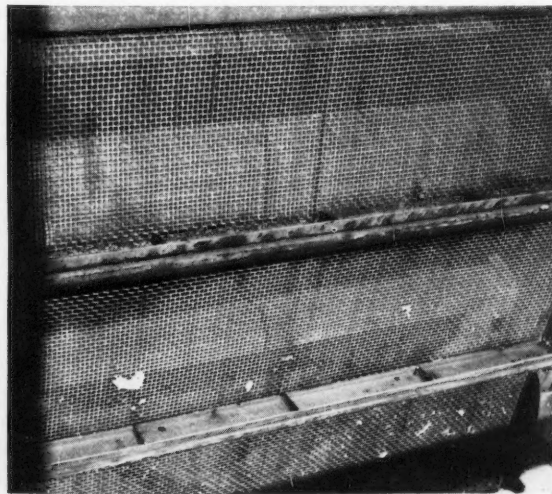
TOPIC OF THE MONTH

Revolving screens used to remove trash from sea water for cooling condensers of Wilmington Harbor Steam Plant of Los Angeles Department of Water and Power.

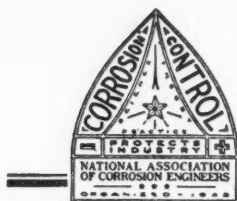


enters the cooling condensers of the Harbor Steam Plant. After 15 months' exposure the plastic paint was in perfect condition, while other trays painted with coal derivative type paints had failed completely and the trays were about one-half rusted away.

Steam plants have many corrosion problems which require constant research and treatment of the water and equipment. The advent of plastic coatings has given the maintenance man a new tool to fight corrosion.



Close up of equipment revealing upper tray one-half rusted away, painted with a coal derivative-type paint. Lower tray painted with plastic paint is in perfect condition after 15 months of service.



NACE News

PLAN FOR NOMINATING NACE OFFICERS APPROVED

The Executive Committee of the NACE Board of Directors has approved a plan worked out by the Policy and Planning Committee for the final nomination of candidates for the offices of President, Vice President and Treasurer of the Association. In accordance with this plan, committees to propose nominees have been set up in each of the Regional Divisions, with the Regional Director in each case serving as Chairman.

Members are invited to send their suggestions for candidates for these

offices to the Chairman of their respective Regional Committee. These suggestions will be discussed by the members of the Regional Nominating Committee, and the results of these discussions and suggestions for nominees for the National offices to be filled will be reported to the Board of Directors of NACE at the time of their meeting in January 1949.

Suggestions from these sources will be used by the Board of Directors in choosing the names of those persons to be finally nominated.

As a guide for members making proposals as to the various candidates, a list of those persons eligible as established by the Article of Organization and By-Laws of NACE, Article V, follows:

H. H. Anderson
E. B. Ayers
P. W. Bachman
L. A. Baldwin
R. A. Brannon
H. B. Britton
S. P. Cobb
Guy Corfield
M. G. Fontana
F. L. Goldsby
L. J. Gorman
T. L. Holcombe

A. N. Horne
F. A. Hough
M. L. Jacobs
V. N. Jenkins
G. W. King
F. L. LaQue
J. T. MacKenzie
G. B. McComb
H. J. McDonald
F. J. McElhatton
R. B. Mears
O. C. Mudd

E. P. Noppel
G. R. Olson
Ivy M. Parker
J. M. Pearson
Robert Pope
W. F. Rogers
E. L. Rolfs
L. F. Scherer
L. R. Sheppard
Arthur Smith, Jr.
D. E. Stearns
H. M. Trueblood
L. G. Vande Bogart

Membership of the various Regional Committees to propose nominees are as follows:

North East Region

- E. P. Noppel, Chairman
Ebasco Services, Inc.,
2 Rector Street,
New York, N. Y.
- L. A. Baldwin
Johns-Manville Sales Corp.,
22 East 40th Street,
New York, N. Y.
- M. W. Ghen
Duquesne Light Co.,
435 Sixth Avenue,
Pittsburgh, Pa.
- R. F. Hadley
Susquehanna Pipe Line Co.,
1608 Walnut Street,
Philadelphia, Pa.
- Robert Pope
Bell Telephone Laboratories,
463 West Street,
New York, N. Y.

North Central Region

- H. J. McDonald, Chairman
Illinois Institute of Technology
3300 Federal Street,
Chicago, Ill.
- H. A. Robinson
Metals Protection Laboratory,
The Dow Chemical Company,
Midland, Mich.
- J. Pat Casey, Jr.
The Crane Company,
836 S. Michigan Avenue,
Chicago, Ill.
- H. F. Haase
Associate Professor of Mechanical
Engineering, Marquette University,
Milwaukee, Wis.
- F. W. Fink
Battelle Memorial Institute,
Columbus, Ohio.

Western Region

- F. A. Hough, Chairman
Southern Counties Gas Co.,
810 S. Flower Street,
Los Angeles, Calif.
- Irwin C. Dietze
Department of Water and Power,
City of Los Angeles,
207 S. Broadway,
Los Angeles, Calif.

C. Kenyon Wells
City of Long Beach Water Dept.,
215 W. Broadway,
Long Beach, Calif.

Chris A. Goldkamp
San Diego Gas & Electric Co.,
Electric Building,
San Diego, Calif.

E. O. Kartinen
Signal Oil & Gas Co.,
811 W. Seventh Street,
Los Angeles, Calif.

South East Region

J. T. MacKenzie, Chairman
American Cast Iron Pipe Co.,
Birmingham, Ala.

G. Gamble
Birmingham Gas Co.,
Birmingham, Ala.

Ivy M. Parker
Plantation Pipe Line Co.,
Bremen, Ga.

E. D. McCauley
American Cast Iron Pipe Co.,
Birmingham, Ala.

E. C. Range
The Okonite Co.,
Atlanta, Ga.

South Central Region

L. F. Scherer, Chairman
Texas Pipe Line Co.,
Texas Building,
Houston, Texas.

R. L. Bullock
Interstate Oil Pipe Line Co.,
Tulsa, Okla.

H. E. Waldrip
Gulf Oil Corp.,
Gulf Building,
Houston, Texas.

T. B. McDonald
United Gas Pipe Line Co.,
Shreveport, La.

I. S. Levinson
Celanese Corp. of America,
Bishop, Texas.

T. R. Statham
Magnolia Pipe Line Co.,
Dallas, Texas.

In all cases, members should forward their suggestions to the Chairman of the committee in their respective Region at their earliest possible convenience.

SELECTION OF RECIPIENTS OF NACE CORROSION AWARDS FOR 1949 BEGINS

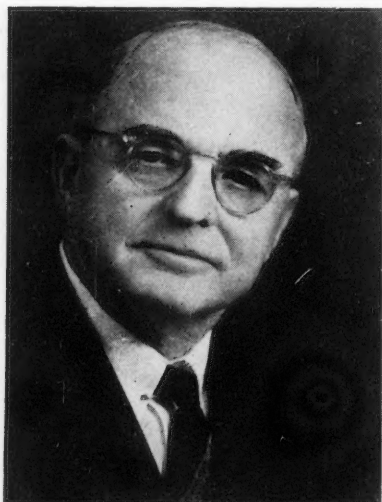
Action of Board of Directors

"The Board of Directors of the National Association of Corrosion Engineers in a regular meeting on January 17, 1947, authorized the presentation annually of two Awards by the Association.

"The Willis Rodney Whitney Award is given in recognition of achievement in the field of corrosion science. This includes the development, study, and analysis of theories, laboratory investigations of important phases of corrosion phenomena, mathematical analyses, etc.

"The Frank Newman Speller Award is presented in recognition of achievement in the field of corrosion engineering. This includes the application of theory to practice, the development of new methods and improvement of existing methods of detecting the presence and severity of corrosion, the development of new methods and improvement of existing methods of alleviating or preventing corrosion, evaluation of economics, etc.

"To administer the selection of nominees for the awards, the Board of Directors shall appoint an Awards



Willis Rodney Whitney



Frank Newman Speller

Committee not later than May 15 of each year. The Committee shall consist of at least six members, one of whom shall be designated by the Board as Chairman. The members of the Committee shall be selected so as to cover the continental United States, preferably with at least one member from each Region. At least 25 percent, but not more than 75 percent of the members shall be reappointed from the Awards Committee of the preceding year, except for appointments to the committee in 1948. No member shall serve for more than three years. A member who is lost by the Committee through resignation, or for any other reason, shall be replaced by appointment by the President of the Association, maintaining the geographical distribution.

"The Chairman of the Awards Committee shall appoint one member as Secretary, who shall record in reasonable detail the discussions within the committee. These records

shall be available to succeeding Awards Committees.

"The Awards Committee shall collect the names of individuals who may be eligible for the awards and shall, by process of elimination, endeavor to select one candidate for each award. The considerations upon which the selections are made shall be the nominee's total contributions in the field covered by the award in question, and shall not be confined to any period of time nor to any branch of such field. The Committee shall not recommend the same individual for both awards in any one year. With respect to either award, it may be recommended that the award be withheld for reasons to be stated in its report. Alternatively, it may recommend a single candidate, if one is agreed upon. In the event of inability on the part of the Committee to reach agreement upon a single candidate, the Committee shall report the names of all persons receiving votes of members of

NEW CORPORATE AND ASSOCIATE MEMBERS

Following is a list of new Corporate and Associate members who have joined NACE during the period from September 16 to October 16, 1948, bringing to 240 the number of these types of sustaining Association memberships:

Apex Smelting Co., Chicago, Ill.	A. J. Peterson
Atchison, Topeka & Santa Fe Railroad Co., Chicago, Ill.	E. E. Chapman
Chesapeake & Ohio Railway Co., Richmond, Va.	C. B. Hitch
Columbus & Southern Ohio Electric Co., Columbus, Ohio	Frank H. Streit
Douglas Aircraft Co., Inc., Santa Monica, Calif.	F. T. Wood, Jr.
Ethyl Corp., Baton Rouge, La.	C. C. Harvey
Jarecki Manufacturing Co., Houston, Texas	W. Howard Pape
Lebanon Steel Foundry, Lebanon, Pa.	E. H. Platz, Jr.
Mathieson Chemical Corp., New York, N. Y.	A. T. Bennett
McKee, Arthur G. & Co., Cleveland, Ohio	D. W. Wilson
Southern Pacific Co., San Francisco, Calif.	E. E. Mayo
White Motor Co., The, Cleveland, Ohio	J. E. Lathe, Jr.

the Committee, and the number of such votes received by each.

"The Chairman of the Awards Committee shall report to the Board of Directors the recommendations of the Committee or the results of its consideration not later than December 15 of each year.

"At a meeting to be held in January of each year, or by letter ballot returnable not later than January 20, the Board of Directors shall determine, by majority vote, whether each award shall be made, and, also by majority vote, the recipient of the award if it is to be made.

"If a single candidate for an award has been recommended by the Awards Committee, the Board of Directors shall vote only upon the question whether the award shall be made, and an affirmative vote upon this question shall constitute the approval by the Board of the recommended candidate.

"If the report of the Awards Committee includes a number of nominees in excess of one with respect to either award, failure of a majority vote by the Board of Directors in favor of some one of these nominees shall constitute determination by the Board that the award in question shall not be made, and shall revoke any earlier action by the Board in favor of making the award.

"After the Board of Directors have elected the recipients of the awards, the President of the Association shall notify the recipients not later than February 1 and may invite each of them to be present at the annual meeting and to present a paper or address at the meeting. The Committee shall arrange to have appro-

priate certificates inscribed for presentation to the recipients of the awards and shall perform any other tasks incidental to the presentation of the awards and prescribed by the Board of Directors."

Awards Committee for 1949

In accordance with the procedure outlined by the Board of Directors, a committee has been appointed to select the awards recipients for 1949. The members of this committee are:

Mr. Walter F. Rogers, Gulf Oil Corporation, Chairman; Dr. F. N. Speller, Pittsburgh, Pennsylvania; Dr. A. Wachter, Shell Development Co., Emeryville, California; Dr. H. J. McDonald, Illinois Institute of Technology, Chicago, Illinois; Dr. I. A. Denison, U. S. Bureau of Standards, Washington, D. C.; Mr. L. G. Vande Bogart, The Crane Company, Chicago, Illinois; Mr. J. C. Stirling, Stanolind Pipe Line Company, Tulsa, Oklahoma; Mr. Sam Tour, 44 Trinity Place, New York, N. Y.; Dr. J. T. McKenzie, American Cast Iron Co., Birmingham, Alabama; Dr. J. M. Pearson, Sun Physical Laboratory, Newton Square, Pennsylvania.

The committee requests that suggestions for the recipients of these two awards be made promptly to the chairman. Nominations should be made on the tabular form provided for this purpose which appears on the next page.

Each member is requested to make his selections at an early date, without fail. The committee wishes to particularly point out that suggestions made in earlier years should be repeated to build a continuous background of possible awards winners.

CANDIDATES SUGGESTED FOR NACE 1949 AWARDS

The following names are submitted as candidates:

1. Speller Award (Engineering)

NAME _____

ADDRESS _____

AFFILIATION _____

CITATIONS* _____

2. Whitney Award (Science)

NAME _____

ADDRESS _____

AFFILIATION _____

CITATIONS* _____

Submitted By _____

Address _____

Date _____

Mail To:

WALTER F. ROGERS
Gulf Oil Corporation
P. O. Drawer 2100
Houston, Texas

* This should include, on a sheet attached, a brief account of work done and references to published reports or technical papers by the nominee, or other evidence of accomplishments that may be easily verified. Letters of endorsement are not desired.

SOMETHING NEW ADDED TO TECHNICAL PROGRAM FOR 1949 NACE CONFERENCE

Continuing the policy of expanding the scope of the Association, two new industry symposia are planned for the 1949 Conference and Exhibition to be held at the Netherland Plaza Hotel in Cincinnati, Ohio, April 11, 12, 13 and 14, 1949. The two industries to be covered by the new symposia are the Transportation Industry and the Pulp and Paper Industry. In order to avoid increasing the total number of industry symposia, the Electrical and Communications Industries will be combined as one symposium and the Water Industry Symposium will not be presented at the 1949 Conference.

Something of an innovation is also planned in the form of a Symposium on the Principles of Corrosion, to be held the first day of the Conference. This symposium is planned to fill the recognized need for a "meeting of minds" of all those interested in corrosion problems regardless of the specific industry in which they are encountered. Accordingly, no other concurrent symposium will be held.

The chairman of this symposium, Hugh J. McDonald of the Illinois Institute of Technology, is arranging an outstanding program to be presented by internationally recognized authorities and educators in the corrosion field. It is believed that this symposium will provide something of interest and value for every individual in the corrosion field from the application engineer to the research worker in the laboratory.

An outstanding program is also

in preparation for the other industry symposia and every effort is being made to maintain a good balance between research papers and those of a more practical nature. Many offers of excellent papers have been received and invitations to participate have been forwarded by the session chairmen to recognized representatives of the industrial fields to be covered in this Conference.

The membership of committees responsible for arrangement of the technical program is as follows:

Technical Program Committee

Chairman: N. E. Berry, Servel, Inc., Evansville, Indiana.

Co-Chairmen: M. G. Fontana, The Ohio State University, Columbus, Ohio. A. Wachter, Shell Development Co., Emeryville, Calif.

Symposium on Corrosion Principles

Chairman: Hugh J. McDonald, Illinois Institute of Technology, Chicago, Ill.

Co-Chairman: Norman Hackerman, University of Texas, Austin, Texas.

Cathodic Protection Symposium

Chairman: H. A. Robinson, The Dow Chemical Co., Midland, Michigan.

Co-Chairmen: R. A. Brannon, Humble Pipe Line Co., Houston, Texas; Irwin C. Dietze, Department of Water and Power, Los Angeles, Calif; Robert J. Kuhn, 2724 Octavia St., New Orleans, La.

Chemical Industry Symposium

Chairman: F. L. Whitney, Monsanto Chemical Co., St. Louis, Mo.

Co-Chairmen: W. C. Fernelius, Syracuse University, Syracuse, N. Y.; Geo. F. Lockeman, Procter & Gamble Co., Cincinnati, Ohio; F. A. Rohrman, University of Colorado, Boulder, Colo.

Electrical and Communications Industries Symposium

Chairman: W. C. Honecker, Indiana Bell Telephone Co., Indianapolis, Ind.

Co-Chairmen: Geo. P. Gamble, Union Electric Co. of Missouri, St. Louis, Mo.; David T. Jones, The Pacific Telephone & Telegraph Co., Los Angeles, Calif.; G. A. Mills, Central

Power & Light Co., Corpus Christi, Texas.

Gas Industry Symposium

Chairman: C. A. Goldkamp, San Diego Gas & Electric Co., San Diego, Calif.

Co-Chairmen: F. J. McElhatton, Panhandle Eastern Pipe Line Co., Kansas City, Mo.; H. S. Riddle, Columbia Engineering Corp., Columbus, Ohio.

General Industry Symposium

Chairman: H. F. Haase, Marquette University, Milwaukee, Wisconsin.

Co-Chairmen: Ralph M. Hunter, The Dow Chemical Co., Midland, Mich.; C. B. Smith, Dearborn Chemical Co., Chicago, Ill.

Oil Industry Symposium

Chairman: M. S. Northup, Standard Oil Development Co., Elizabeth, N. J.

Co-Chairmen: J. C. Stirling, Stanolind Pipe Line Co., Tulsa, Okla.; A. Wachtler, Shell Development Co., Emeryville, Calif.

Protective Coatings Symposium

Chairman: George Diehlman, National Lead Co., Brooklyn, N. Y.

Co-Chairmen: R. P. Devoluy, C. A. Woolsey Paint & Color Co., Inc., New York, N. Y.; Geo. W. Seagren, Mellon Institute of Industrial Research, University of Pittsburgh, Pittsburgh, Pa.; Arba H. Thomas, American Rolling Mill Co., Middletown, Ohio.

Pulp and Paper Industry Symposium

Chairman: L. G. Vande Bogart, The Crane Co., Chicago, Ill.

Co-Chairman: G. H. Pringle, Mead Corp., Dayton, Ohio.

Salt Water Corrosion Symposium

Chairman: A. W. Tracy, American Brass Co., Waterbury, Conn.

Co-Chairmen: C. P. Larrabee, Carnegie-Illinois Steel Corp., Vandergrift, Pa.; L. Malcolm Mosher, Bethlehem Steel Co., Quincy, Mass.

Transportation Industry Symposium

Chairman: J. M. Trissal, Illinois Central Railroad, Chicago, Ill.

Co-Chairmen: A. E. Archambault, New York Central Railroad, New York, N. Y.; L. W. Smith, Cornell Aeronautical Laboratory, Inc., Buffalo, N. Y.

TANK COATING INSPECTION TOUR HELD BY WEST TEXAS SECTION

From the registration Tuesday morning, September 14, through the barbecue Thursday evening, September 16, the Third Annual West Texas Inspection Tour was a complete success. Under the sponsorship of the West Texas Section of the South Central Region of NACE, this year's tour attracted 112 registrants from virtually all regions of the country to the rich Permian Oil Basin surrounding the Midland-Odessa area.

Inspecting engineers spent the first two days of the tour examining over 40 field installations, including interiors of lease tanks, sucker rods, tubing and treaters which had been subjected to corro-

sive sour crude conditions for from one to seven years and which had been protected by coatings supplied by a dozen leading protective coating manufacturers. After the first tour, an interesting discussion, led by W. H. Crenshaw, of the American Inspection Co., Midland, was held Monday evening. J. A. McRae, Minnesota Mining and Manufacturing Co., was chairman of the Forum and Report session Tuesday night. Many engineers expressed the need for standardization of terms and conditions in future coating field tests.

The third day of the inspection was spent touring tube coating plants in the vicinity, where manu-



Some of the 112 who attended West Texas meeting.

facturers and applicators participating in the tests displayed and demonstrated the latest proved techniques in the cleaning and coating of oil field equipment for use in sour crude production. A very enjoyable barbecue concluded activities Thursday evening.

In general, the tests indicated the economic feasibility of coatings on sour crude production equipment, but because of the short duration of the tests and the limited data

available to date, an accurate account of the actual savings to be realized could not be made.

The expanded scope of this year's tour over the two previous ones was evidenced by the doubling of last year's attendance and the increase in units inspected. A final report of the 1948 tour will be prepared for all registrants, and additional copies will be made available, at a nominal cost, to those desiring details of the inspection results.

NORTH EAST REGION BOARD MEETS

L. B. Donovan, Secretary-Treasurer of the North East Region reported the following action took place during the meeting of the Board of Trustees of the North East Region, September 9, 1948:

"Members present: A. S. Brookes, R. H. Lynch and L. B. Donovan.

"The following members were suggested to constitute a nominating committee for Regional Officers for the calendar year 1949: E. P. Noppel, A. V. Smith and R. B. Mears.

"A tentative date for the first general Regional meeting of the year, to be held in conjunction with the Philadelphia Section meeting, was established as the week of November 14. The second general Regional meeting will be held in conjunction with the Metropolitan New York Section at a date to be announced later during the month of December.

"A communication was received from E. F. Wolf of the Consolidated Gas and Electric Light and Power

Company of Baltimore dated September 1, 1948, in which he states, 'I expect to meet with other local members shortly to discuss plans for Baltimore activities of the Association.'

"It was suggested that the National Director take up the question of including Eastern Canada in the North East Region at the next national meeting.

"Necessary papers were executed to establish as a depository for the Region funds the National City Bank of New York, Fourteenth Street Branch.

"The program of the two-day South Central Regional meeting, held in Tulsa, Oklahoma, September 20-21, was reviewed.

"Members of the Association residing in the Philadelphia area have been notified that their petition for recognition as the 'Philadelphia Section' of the North East Region has been unanimously approved by the Region Board of Trustees, and the Philadelphia group has been instructed to hold a business meeting to elect officers."

The Chicago Section of the North Central Region of NACE is now a member of the Chicago Technical Societies Council. This will permit the notices of section meetings to appear in the Scien-Tech News, a publication which has a circulation of several thousand copies among the members of technical societies in and near Chicago.

The Shreveport Section held an informal get-together and barbecue at the 40 and 8 club October 14.

Advised that their petition for recognition as a Local Section had

been approved by the Board of Trustees of the North East Region, members of NACE who reside in Philadelphia called a meeting October 12, and elected officers:

Chairman—H. L. Hamilton, Keystone Pipe Line Co.

Vice Chairman—A. V. Smith, Consulting Engineer.

Secretary-Treasurer—E. R. English, H. C. Price Co.

The newly formed Section will next meet November 17, 1948, in the Engineers' Club. The North East Regional meeting will be held at the same time and place in Philadelphia under the auspices of the Section.

South Central Region held a meeting Sept. 20-21, 1948, in Tulsa, Okla. Fourteen papers were presented during the four technical sessions. Nominees for 1949 offices are: Nathan Schofer, Chairman; A. L. Stegner, Vice Chairman; T. R. Statham, Secretary-Treasurer, and M. C. Fleming, Assistant Secretary-Treasurer. Registrations totaled 261.

South East Region has scheduled a dinner meeting for November 27 at the Henry Grady Hotel, Atlanta, Ga. I. A. Denison, National Bureau of Standards, Washington, D. C., will be the principal speaker, with the topic, Underground Corrosion. Kirk H. Logan, also of the Bureau, is scheduled to lead an open discussion on Electrolysis.

Houston Section met Oct. 18 in the Houston Engineers' Club. Thirty-nine registrants heard D. B. Crawford, present the paper, Unusual Corrosion Problems in the Chemical Industry. The next meeting of the Section will be held November 15 in conjunction with the American Society of Mechanical Engineers.

GENERAL INTEREST

The Research Committee of the American Electroplaters' Society announced the establishment of a second fellowship at Princeton University to intensify the study of the nature and effects of porosity in electrodeposits. The first fellowship, established in 1946, has already developed a unique and original method for studying porosity. The electrodeposited foil is stripped from the base metal and its permeability to a gas is measured. Experimentally, a characteristic constant for each metal is obtained. This is the time required to reduce a given pressure difference across the foil to half its original value. Preliminary work indicates that there is a linear relationship between the logarithm of the half-time and the thickness. The Research Committee believes that this method gives the first reproducible quantitative measurements on porosity that have been obtained anywhere or anytime.

International Nickel joins the 1948 National Metals Exposition and Congress, whose theme is a "Salute to Alloy Steels," with a panorama of the historical development and modern uses of alloys containing nickel. Featured will be performance data based upon the service rendered by engineering alloy steels over long periods of use and a pictorial record showing the individuals who, since 1751 when Cronstedt first isolated nickel, made major contributions toward today's widespread use of nickel. Members of

the company's Development and Research Division will be available for discussion of the properties, treatment, fabrication and performance of engineering alloy steels and stainless steels, as well as cast irons, brasses, bronzes, nickel silver, cupronickel, Monel, Inconel and other nickel alloys. The Exposition and Congress will be held at the Commercial Museum and Convention Halls, Philadelphia, Pa., October 25-29.

A schedule of national and district meetings of American Society for Testing Materials is announced as follows:

NATIONAL MEETINGS

1949 (Fifty-second) Annual Meeting, Chalfonte-Haddon Hall, Atlantic City, N. J., June 27 to July 1, inclusive.

1949 Spring Meeting and ASTM Committee Week, Hotel Edgewater Beach, Chicago, Ill., February 28 to March 4, inclusive.

1949 West Coast Meeting (first national meeting of ASTM on the West Coast), Fairmont Hotel, San Francisco, Calif., October 10 to 14, inclusive.

DISTRICT MEETINGS

(The following meetings are usually technical sessions sponsored by the ASTM district in the area indicated.)

Philadelphia District, Franklin Institute, October 13.

New Feature to Be Introduced

With the introduction of the new size Corrosion magazine in January, a Questions and Answers Department will be incorporated under the title of "Corrosion Problems." The new feature will be edited by L. G. Vande Bogart of the Crane Co., Chicago, Illinois.

Questions will be given a serial number and may be reworded by the Editor. Questions should carry sufficient detail to completely describe condition and problem. Proprietary trade names may be used in presenting problem, but the editor reserves the right to reword both questions and answers before publication in order to delete such trade names. Selected questions will be printed, and readers are invited to send in answers. Where answers are incomplete or there is a disagreement, a committee will screen answers and decide on an answer or agree to print various viewpoints.

All questions will be the property of the Association. The questions which are not printed will be circulated to the above committee and answers sent to the correspondent privately.

Authors of questions will remain anonymous to readers while authors to answers may remain anonymous by request. In general, it will be better to have names of authors of answers. Authors of both questions and answers should give name and company affiliation and submit them to: L. G. Vande Bogart, 836 South Michigan Ave., Chicago, Illinois.

Washington District, Wardman Park Hotel, Washington, D. C., October 14.

Chicago District, 83 E. Randolph St., Chicago, Ill., October 19.

St. Louis District, Engineers Club, St. Louis, November 4.

Philadelphia District, Franklin Institute, November 10.

Cleveland District, Cleveland Engineering Society, November 16.

New England District, Hotel Sheraton, Worcester, Mass., November 19.

Pittsburgh District, Mellon Institute, November 29.

New York District, Engineering Societies Building, October 26.

New York District, Engineering Societies Building, December 3.

Philadelphia District, Franklin Institute, January 13.

New York District, Engineering Societies Building, February 3.

Philadelphia District, McCallister's, 1811 Spring Garden St., February 10.

Philadelphia District, Franklin Institute, March 22.

TECHNICAL MEETINGS

Committee D-3 on Gaseous Fuels, October 3, Atlantic City, N. J.

Committee D-10 on Shipping Containers, October 7, 8, Chicago, Ill.

Committee C-16 on Thermal Insulating Materials, October 11, 12, Atlantic City, N. J.

Committee B-8 on Electrodeposited Metallic Coatings, October 13, 14, New York, N. Y.

Committees C-1 on Cement, C-7 on Lime, C-9 on Concrete and Concrete Aggregates, D-4 on Road and Paving Materials, October 26-29, St. Louis, Mo.

Committee D-2 on Petroleum Products and Lubricants, November 13-16, Chicago, Ill.

Committee D-20 on Plastics, November 16, 17, Atlantic City, N. J.

Committee D-9 on Electrical Insulating Materials, November 17-19, Atlantic City, N. J.

Committee C-19 on Structural Sandwich Constructions, November 18, 19, Philadelphia, Pa.

Committee A-1 on Steel, January 24-26, 1949, Pittsburgh, Pa.

PERSONALS

Major W. S. Bradford has resigned as treasurer of the Shreveport Section of the South Central Region of NACE, and severed his connection with the Arkansas-Louisiana Gas Co., to return to active duty with the U. S. Army, with headquarters in Washington, D. C.

Carl E. Schmitz, vice president and director of engineering of the Crane Packing Co., Chicago, Ill., has been appointed a member of the Annual Awards Committee of the American Society of Lubrication Engineers. This committee annually awards the Alfred E. Hunt Memorial Medal, affords two persons honorary life membership awards in ASLE, and also presents an annual Junior Award. Mr. Schmitz is also an active member of NACE.

Alex Stewart has been appointed Research Director for the entire National Lead Co., comprising all the technical activities of the company in this country and abroad. Mr. Stewart, who was born near Philadelphia in 1892, studied at Pratt Institute and Brookings Institute. While working for National Lead in 1908 during summer vacations he became interested in chemistry. After completing his studies he worked for Wringwalt Linoleum Co., for two years and then joined the C. L. Constant Co., a mining engineering concern. He returned to National Lead in 1930, and served as development engineer until 1938, at which time he was appointed Research Director of the parent laboratory of

the Company. His interest in corrosion has been in the field of protective coatings, where he holds at least one basic patent. He maintains his headquarters in the Executive Offices of the Company at 111 Broadway, New York, N. Y.

Russell Brannon and **L. G. Sharpe**, Houston, Texas; **A. T. Clothier**, Tulsa, Okla.; **Bob Martin**, **George Jeffares** and **Ivy M. Parker**, Atlanta, Ga., were visitors at the New York Local Section meeting held September 29, 1948.

Forrest E. Allen, formerly a member of the faculty of Iowa State College in the Department of Mechanical Engineering, and Associate Professor in charge of the instruction on metallurgy, has joined the Development and Research Division of The International Nickel Co., Inc. He will make his headquarters in New York, and will work on the Company's educational program with universities and colleges of the United States.

Staff changes announced by the Carborundum Co., Niagara Falls, N. Y., are as follows: **E. B. Forse**, presently manager of the Refractories Division at Perth Amboy, N. J., appointed assistant vice president; **C. E. Hawke**, presently director of sales, Carborundum Co., appointed manager of the Refractories Division; **E. R. Baxter**, appointed director of sales and sales administration, and **G. R. Rayner, Jr.**, named assistant director of sales administration.

NEW PRODUCTS, MATERIALS AND SERVICES

Literature

A tubing caliper service has been added to the list of tubular inspection services provided by the Tubular Service and Engineering Co., (Tuboscope) Houston, Texas. The caliper service will feature the Kinley caliper, which incorporates a number of improvements for accurately surveying tubing in wells, such as simultaneous determinations of rod wear and corrosion plus increased speed of making a complete survey. The first Tuboscope Tubing Caliper field service point has been established in Kilgore, and the company has plans to extend the service to other areas.

Four new specifications for arc-welding electrodes recently completed by the Committee on Filler Metal, jointly sponsored by the American Welding Society and the American Society for Testing Materials, are as follows: Tentative Specifications for Mild Steel Arc-Welding Electrodes; Tentative Specifications for Low-Alloy Steel Arc-Welding Electrodes; Tentative Specifications for Corrosion-Resisting Chromium and Chromium-Nickel Steel Welding Electrodes, and Tentative Specifications for Copper and Copper-Alloy Metal Arc-Welding Electrodes. Individual copies of the specifications are available from either the American Welding Society, 33 West 39th Street, New York, 18, N. Y., or The American Society for Testing Materials, 1916 Race Street, Philadelphia 3, Pa., at 25 cents each.

The measurement of the existent corrosivity in used engine oils gives an important criterion of the onset of the breakdown of the oil. Nearly all crankcase oils contain either natural or added substances which inhibit the oxidation of the oil under the extremes of temperature and agitation which exist in an engine. The standard test for the ability of an oil to resist break down is the Chevrolet L-4 Test. Randall and Sons, 2512 Etna St., Berkeley 4, Calif., have just issued two information circulars which describe the application of the step-plated strip to the obtaining of supplementary information which will give the rate of rapid onset of corrosive characteristics in the oil under test by the L-4 method, and several other laboratory evaluation tests. The test is made by using the strip as the stirrer in a heated cup of the oil and then reading visually the number of steps of lead plate corroded off the copper strip. Another suggested use of the strip is to test the efficiency of inhibitors in used acid pickling baths, the corrodibility of factory wastes and foodstuffs, the effectiveness of protective coatings.

Metallurgists of the Jones & Laughlin Steel Corp., report that a new phosphate material which inhibits rusts and helps lubricate wire in process permits a 20 to 25 percent increase in speed of drawing fine high-carbon wire. The material, known as Banox and described by

the manufacturer, Calgon, Inc., as an amorphous metaphosphate compound, has been in use at J & L's Aliquippa, Pa., wire mill since June 1947. Service engineers report this as the first application of the material in wire drawing, although it has been successfully employed by manufacturers of household appliances, metal furniture, and automotive bodies and parts, as a rust-proofing and paint-bonding coating prior to painting. Full information is available from Calgon, Inc., Pittsburgh, Pa.

A revised 36-page catalog, Number 1101-J, has been published by the C. J. Tagliabue Corp. (N. J.), manufacturer of indicating, recording and control instruments for temperature and pressure. The catalog illustrates and describes the complete line of instruments manufactured by the company. Catalog 1101-J is available from C. J. Tagliabue Corp., 614 Frelinghuysen Ave., Newark 5, N. J.

A high speed hacksaw blade which is claimed to be shatter-proof and unbreakable has been introduced by the Millers Falls Co., Greenfield, Mass., under the trade name, Jet-Edge. The blade is said to have reduced cutting costs 20 to 50 percent for a number of industrial users under exceptionally tough testing conditions.

A contact-making thermometer, combining the features of an indicating thermometer in addition to an alarm or control device, has been introduced by the Weston Electrical Instrument Corp., 617 Frelinghuysen

Ave., Newark 5, N. J. The thermometer can be supplied to make contact on either increasing or decreasing temperatures. Accuracy as an indicating thermometer is ± 1 percent; and as a control device ± 1.5 percent of the full scale. Literature is available from the manufacturer.

Oakite Products Inc., New York 6, N. Y., has available an interesting folder describing their product, Composition No. 15, a cold solvent material designed to permit fast, thorough removal of paint and similar films from metal surfaces. Used at room temperature, it may be applied by tank immersion method or by swabbing or brushing.

Ceilcote Co., Cleveland, Ohio, has data on their new acid and alkali-proof lining for fume carrying ducts. Manufactured under the trade name Ceilcote Spray Grade, it has a maximum resistance of 300° F. and bonds to either wood or metal. Application is by special spray equipment.

Literature describing their improved self-aligning roller bearing units is available from the Shafer Bearing Corporation, 801 Burlington Ave., Downers Grove, Ill.

• *Reprints of the article Management Information on Cathodic Protection of Buried Metallic Structures Against Corrosion by the Correlating Committee on Cathodic Protection are now available in small quantities. This reprint which was originally published in the September, 1948, issue of CORROSION may be purchased from the Association in lots of ten or more at a cost of ten cents each. Orders should be addressed to: National Association of Corrosion Engineers, 905 Southern Standard Building, Houston 2, Texas.*



Corrosion Abstracts

ATMOSPHERIC CORROSION

Investigations Into the Resistance Properties of Some Aluminum-Zinc-Magnesium Alloys in Tropical Service. Bollenrath & Bungardt, Z. W. B., *Report U. & M. 1072, TPA3/TIB translation GDC.10/5680T* (1943); 25th Sept. *Hyduminium Abst. Bull.* (England) 17, Nos. 1 and 2, (1948) Jan., Feb.

Discusses results of strength and stress corrosion tests on sheets of different aluminium-zinc-magnesium alloys weathered for 6 months in North Africa, and the variation in shear strength of rivets in similar alloys after storing under tropical conditions. It is concluded: (1) The strength properties of the alloys investigated change considerably with ageing particularly in cold-age state. Owing to progressive age-hardening the yield point and ultimate strength increase while the elongation decreases only slightly. (2) Corrosion attack is more intensive on the coast than inland particularly with thin

sheets. The attack takes place principally by local pitting, and intercrystalline corrosion was not observed. (3) The shear strength of aluminium-zinc-magnesium alloy rivets exceeds 30 kg/sq.mm. (10#/sq. in.). It was noted that alloys enriched by vanadium and chromium remained resistant to stress corrosion after water quenching and under increasingly stringent corrosive conditions. Results of weathering tests in Catania reported in an appendix.—ALL.

CATHODIC PROTECTION

Cathodic Protection of Underground Structures. N. P. Peifer, *The Manufacturers Light & Heat Co., Corros. & Matl. Prot.* 5, No. 1, 6-9 (1948) Jan.-Feb.

Discusses surveys relative to location of areas where cathodic protection may be necessary, and use of expendable electrodes to secure this protection. Recent development has been use of magnesium ribbon anode. This has a steel core and is

Abbreviations at the end of abstracts indicate source of abstract and contributor; and are as follows:

AER	Aeronautical Review, Institute of Aeronautical Sciences, Inc.
ALL	The Abstract Bulletin, Aluminum Laboratories, Ltd.
AWWA	Journal, American Water Works Association
BLR	Battelle Library Review, Battelle Memorial Institute Library
BNF	Bulletin; British Non-Ferrous Research Association
CALCO	Calco Chemical Division, American Cyanamid Corp.
CE	Chemical Engineering, McGraw Hill Publishing Co.
CEC	Consolidated Edison Co. of New York, Inc.
EW	Electrical World, McGraw Hill Publishing Co.
GPC	General Petroleum Corp. of California
INCO	The International Nickel Co., Inc.
IP	Institute of Petroleum
MA	Metallurgical Abstracts, Institute of Metals, London, Eng.
MR	Metals Review, American Society of Metals
NBS	National Bureau of Standards
RA	Refrigeration Abstracts, American Society of Refrigeration Engineers
RM	Revue de Metallurgie, Paris, France
RPI	Review of Current Literature Relating to the Paint, Colour, Varnish & Allied Industries, Research Association of British Paint, Colour & Varnish Manufacturers, London.
UOP	Universal Oil Products

plowed into the ground near the pipe to be protected. As used at present this ribbon has a cross section of $\frac{3}{8}$ in. by $\frac{3}{4}$ in. The steel core is connected to the pipe to be protected at distances not greater than 1000 ft.—CEC.

Cathodic Protection of Pipelines (Use of Magnesium Anodes). H. Seymour, *Min. Mag.*, 76, No. 6, 339-340 (1947).

Corrosion of metal surfaces in the presence of moisture is for the most part electrolytic, and may be greatly reduced or prevented entirely by the use of an expendable and replaceable anode. A proper alloy composition of the anode, and a suitable backfill surrounding it are essential to electrical efficiency, while the c.d. is an important factor. The specification range of suitable magnesium alloys is: aluminium 5.3-6.7, manganese (minimum) 0.18, zinc 2.15-3.5, silicon (max.) 0.3, copper (max.) 0.05, nickel (max.) 0.003, iron (max.) 0.003, other impurities (max.) 0.3 percent, magnesium remainder. A review of the value of magnesium in cathodic installations is given.—MA.

Location and Selection of Anode Systems for Cathodic-Protection Units. D. B. Good, *Corrosion*, 3, 539-548 (1947) Nov.

In locating anodes for the cathodic protection of pipelines, soil resistivity should be measured and taken into account. This may be measured by the "four-bar" method, with a Megger. Curves are presented, from which the most economical length of anode from soil of given resistivity may be estimated on a cost basis.—MA.

CHEMICAL CORROSION

Corrosion Resistance of Nickel Base Alloys and Applications in Processing Equipment. R. B. Long, Haynes Stellite Co., Paper, before Sym. on Modern Metal Protection, Cleveland, Oct. 27, 1947; abstr. *Steel*, 121, No. 18, 132-134 (1947) Nov. 3.

Four types of nickel-base Hastelloy alloys developed for extremely corrosive conditions are described. Alloy A (20% molybdenum—20% iron) and Alloy B (30% molybdenum—5% iron) are resistant to hydrochloric and other reducing acids and to reducing corrosive salts. Alloy A at temperatures up to 170° F. and Alloy B at temperatures up to and sometimes above the boiling point and at higher pressures. Alloy C (17% molybdenum, 15% chromium, 5% tungsten and 5% iron) has all-round corrosion resis-

tance. Alloy D (10% silicon, 3% copper and 1% aluminum) has outstanding resistance to sulfuric acid.

The Behavior of Alloys in Sea Water at High Velocity. F. L. LaQue, Inco & W. C. Stewart, U. S. Naval Eng. Exper. Sta., Paper before Internat. Congress on Corrosion, Paris, (1947) Oct. 7. *Steel*, 121, No. 20, 128 (1947) Nov. 17.

Tests in brackish water do not serve adequately to disclose the behavior of all compositions in full strength sea water, nor does synthetic sea water serve adequately to disclose the behavior of alloys in contact with natural sea water at high velocity. Water velocity, temperature, aeration and water composition can be studied by means of three types of apparatus which are described. In general, erosion or corrosion by sea water increases with temperature and water velocity. The presence of air bubbles, injurious to certain alloys, has no effect on or is even beneficial to others.—INCO.

Oil-Filled Valve Trap Mitigates Corrosion on Furfural Solvent Lube Refining Unit. E. K. Dewey, Jr., Continental Oil Co., *Petro. Processing*, 2, 913 (1947) Dec.

Corrosion of a processing tower relief valve on a furfural lube extraction unit at the Ponca City refinery of Continental Oil Co. was reduced by looping the conduit to the valve and filling the loop with an SAE 30 type oil to form a trap preventing contact of corrosive tower liquid with the valve. A connection for draining and filling the trap is provided.

Corrosion. New Malleable Austenitic Steel. M. G. Fontana, *Ind. & Eng. Chem.*, 40, No. 1, 89A-90A (1948) Jan.

The new malleable austenitic Ni-Resist developed by American Cast Iron Pipe Co. (15% nickel-3% chromium-6% copper-2% silicon-1.25% manganese-2.3% carbon) and recent developments in Ni-Resist compositions described. Comparative corrosion tests of malleable austenitic and gray austenitic cast iron rods at room temperature in 1%, 10%, and 25% Sulfuric Acid (H_2SO_4), 3% Sodium Chloride (NaCl) and 0.5%, 1%, 5% and 10% hydrochloric acid (HCl) conducted by W. C. Leslie and E. Mead at Ohio State University are tabulated. Tests showed no essential difference in corrosion resistance. The malleable iron has, on the other hand, a tensile strength of 70,000 lbs. psi., yield strength of 50,000 lbs. psi., Brinell hardness of 80-200, and elongation of 5%. Chief applications enumerated.

Characteristics of Types 3, 4 and 5 Ni-Resist briefly discussed and composition ranges of all Ni-Resist types tabulated.—INCO.

Rossaul Copper-Brite Solution Removes Oxides, Is Non-Fuming. *Am. Machinist*, 92, No. 4, 166 (1948) Feb. 12.

A solution for bright dipping of copper and copper alloys called "Copper-Brite" removes oxides and leaves metal bright, resistant to future tarnish or discoloration and does not discolor silver solder. Metal is left passivated and ready for next operation. Can be used at room temperature in acid-resistant still tanks. Announced by Rossaul Co. N. Y. C.—INCO.

Corrosion-Resistance of Stainless Steel. *Corros. & Matl. Prot.*, 4, No. 6, 28 (1947) Nov.-Dec.

When hauling corrosive materials, trailers of stainless steel have at least three times the life expectancy of other types of construction. The meat business is hard on trailers due to the chemicals in blood and the brine salt, and ice solutions used for refrigeration. A trailer used in the scrap aluminum and magnesium business shows no deterioration even though it is parked at night in the magnesium smelting department, where fumes are decidedly harmful to ordinary steel. Operators who traverse coastal routes report stainless steel trailers superior in withstanding salt air. Mfg. by Fruehauf Trailer Co.—INCO.

A Cyclic Process of Sulfuric Acid Manufacture at Trail, B. C., Canada. A. F. Snowball, Paper before CIC Mtg. at Banff, June 8-11, 1947; *Canad. Chem. & Proc. Inds.* 13, No. 12, 1110-1114 (1947) Dec.

A flow sheet of the process which uses a vanadium catalyst instead of platinum is given, as well as details of the equipment, instrumentation and materials of construction. Corrosion problem in the converters at 650° C. caused testing of mild steel, cast iron with ½ molybdenum, calorized coatings and chromium-silicon alloy. At 650° C. mild steel showed a corrosion rate in 25% sulfur dioxide, 37.5% oxygen, 37½% nitrogen of 0.39 gm/sq. in. in 24 hrs. Aluminum coated samples showed no appreciable corrosion. Graphs show conversion ratios and corrosion rates.—INCO.

Corrosion of Aluminum and Aluminum Alloys in Aqueous Media at Various Temperatures. H. U. Von Vogel, *Korros. u. Metallschutz*, 16, 259-278 (1940); *Brit. Absts.*, B1, 169 (1947) May.

99.99, 99.8 and 99.5 aluminum, Mangal,

Silumin, K. S. Seewasser, Pantal, B. S. Seewasser, homogenized B. S. Seewasser, and Mangal, Pantal and 99.5 aluminum clad with 99.9 aluminum were tested in inorganic and organic acids, alkalis, salts, and photographic solutions, at 25°, 50°, and 98° and corrosion determined by macro- and micro-examination. Results graphed and tabulated. General conclusions are: 1) where corrosion is appreciable at 20°, it is greatly enhanced by higher temperatures; 2) in solutions of pH < 3.5, corrosion is severe with all materials; in acid solutions of pH > 3.5, 99.99 aluminum is most resistant, followed in order by 99.8 and 99.5 aluminum, Mangal, Silumin, Pantal, K. S. Seewasser and B. S. Seewasser; 3) in alkaline solutions of pH < 10, alloys containing magnesium are superior owing to formation of protective films of high magnesium content; in solutions of pH > 10, no protective films are formed and all materials corroded rapidly.—INCO.

COATINGS

Some Factors Affecting the Corrosion of Packaged Metal Parts. C. G. Lavers, A. H. Woodcock, & J. A. Pearce, *Corros. & Matl. Prot.*, 4, 6-10 (1947) Nov.-Dec.

Describes some factors affecting the efficiency of intimate wraps and carton overwraps in preventing corrosion. The work was done on connecting-rod-bearing liners of steel faced with a copper-lead alloy; on roller-bearing cups of steel with a polished bearing surface; and on push rods (hollow cylindrical steel parts with a polished exterior). Various types of pre-cleaning, grease or oil coating, wax-dipping, coated paper, or fiberboard packing were evaluated. Tests were carried out in cabinets at 80° F. and 100% relative humidity, or 120° F. and 55% humidity.

Paint and Corrosion Division of the Central Instituut voor Materiaalonderzoek. I. H. Van der Veen, *Verfkroniek*, 16, 21-23+ (1943); *Brit. Absts.*, C Pt. 1, 17 (1947) Feb.

Apparatus used by the Institute for the semi-technical preparation, application, weathering and testing of paints and varnishes is described.—INCO.

Corrosion-Resistant Finish. *Die Castings*, 5, No. 12, 70 (1947) Dec.

A new product, Finish No. 146, which can be used as a clear, corrosion-resistant finish on steel or as a bond for subsequent application of paint, lacquer or enamel

over steel, aluminum, zinc, copper or magnesium alloys is introduced by The Mitchell-Bradford Chemical Co. This finish, which can be either air dried or baked, can be furnished clear or tinted, and may be applied by dipping, spraying or brushing. Sample aluminum panels are available to which Finish No. 146 was applied over the entire surface, and on one side a coating of synthetic enamel was sprayed and baked over the No. 146. When these panels are bent back and forth, the coating does not chip or flake until the endpoint is reached at which the panel breaks.—INCO.

Has Electrolytic Tinplate Come to Stay in the U. S. A.? *Tin*, 20 (1947) Mar.

The development of the technique during the war of electrodepositing tin at high speeds and high c.d. resulted in the establishment in the U.S.A. of large plants for the manufacture of electro-tinplate. Constructed originally with an eye on a possible scarcity in tin, these plants today supply electrolytic tinplate to a widening market. While hot-dipped tinplate holds almost the whole market in Great Britain, in America the percentage of electrolytic to hot-dipped tinplate was 47% in 1946. A revised conservation order permitting a wider scope for electrolytic tinplate than before is another sign that it has come to stay in the U.S.A.—MA.

Painting Metal Casements. G. L. Masteron, *Decorator*, 46, No. 542, 46-67 (1947).

The difficulties encountered in painting metal casements are stressed. Pretreatment of the frames by the manufacturer has an important bearing upon the final finish obtained. Chemical pretreatment is found to give the best results.—RPI.

Functions of Organic Coatings in Present Day Engineering Problems. J. J. Mattiello, *Paint & Varnish Prod. Manager*, 27, 300-304 (1947) Nov.

Discusses surface preparation; electrical insulation; food and chemical containers—metal; marine paints; structural steel painting; naval-aircraft paints; railroad paints; infrared reflecting paints; other engineering fields; plastics vs. organic coatings; and economics.—BLR.

Tests for the Corrosion Resistance of Lacquer Coatings for Food Cans. H. Ketterl, *Korros. u. Metallschutz*, 20, 30-7 (1944); *Chim. et Ind.*, 52, Nos. 1-6, 81 (1944).

Porosity is determined electrolytically

using an apparatus, due to Niesen-Röhre, in which the support can be deformed, during measurement, by a method similar to the Erichsen machine. Chemical resistance tests carried out with laboratory solns. are more drastic than practical exposure, since protective colloids are present in canned foods.—RPI.

Modern Paints and Lacquers for Use on Metals. H. Krause, *TZ Prakt. Metalbearb.*, 51, Nos. 7-8, 258-259; *Ibid.*, Nos. 9-10, 316 (1941); *Chim. et Ind.*, 47, No. 3, 261D (1942).

Materials mentioned as anti-corrosive paints for iron include red lead paints, coumarone resin paints (including coumarone resin/N.C. lacquers) coal-tar and pitch paints, benzyl cellulose lacquers, and chlorinated rubber paints.—RPI.

Stress in Electrodeposited Metals. A. W. Hotherhall, *Symposium on Internal Stresses (Institute of Metals)*, 107-118 (1947) Oct.

Methods of measurement. Chromium, cobalt, copper, iron, nickel and silver are normally deposited in a state of tensile stress; cadmium, lead, and zinc are generally in compressive stress. Magnitude and sometimes direction of stress varies with conditions of deposition. 26 ref.—BNF.

Possibilities of Zinc Coatings on Drill Pipe. L. R. Jackson & others, *Drilling Contr.*, 3, 50-51 (1947) Oct. 15.

Zinc plating, even when scratched, greatly prolongs the operating life of steel under test conditions simulating drill-string service, according to report prepared at Battelle Memorial Institute. Zinc coating stood up much better than plastic coatings under the same test conditions.—BLR.

How to Paint Metal. W. D. Jarvis, *Western Paint Rev.*, 32, No. 12, 15-17+ (1946); *NPVL Abstr.*, No. 121, 82 (1947).

The preparation of metal surfaces for painting, the types of paint used, and the application, are discussed.—RPI.

CONDENSATE WELL CORROSION

Corrosion in Water Flooding Operations. F. Prange, Phillips Petro. Co., Paper, Kan.-Okla. Water Flood Operators, Independence Kan., Dec., 1947; abstr. *Producers Month.*, 12, No. 38 (1948) Jan.

The three principal causes for corrosion in water flooding operations are acids, air, and stray electric currents. The following preventive measures are suggested: (1) Keep air out of the fluid

(2) Use protective coatings such as cement-lined pipe. (3) Use corrosion resisting materials where applicable, e.g. copper alloys and non-metallic pipe. (4) Apply cathodic protection to prevent external corrosion. Insulating flanges or nipples may be used to interrupt stray currents. (5) Add inhibitors to change the nature of corrosive media. Cement-lined pipe is satisfactory in water-flood operations, although lime is soluble in acids. Present organic or plastic coatings contain pinholes and are permeable to water. In the subsequent discussion it was pointed out that formaldehyde is injected in producing wells to prevent hydrogen sulfide corrosion by depositing a protective film which forms only in the presence of hydrogen sulfide water. The use of sodium chromate to prevent oxygen corrosion is not economically feasible in water flooding.

Experiments Aimed at Control of Corrosion in Gas Wells Described. D. A. Shock, NGAA, Paper before ACS Regional Mtg. Houston, Tex., Dec. 13, 1947; *Oil & Gas J.*, **46**, No. 33, 53 (1947) Dec. 20.

The chief corrosive factor in high pressure gas wells is carbonic acid. When carbon dioxide accounts for more than 15 psi of the total pressure, severe corrosion occurs. Acetic acid is only a moderately corrosive factor. Data not given.—INCO.

Corrosion Control in Mid Continent Production. C. C. Munger, *World Oil*, **127**, 172-174, (1947) Dec.

A general discussion of types of corrosion taking place, content of corrosive materials in various fields, and methods used to combat it.—BLR.

CONSTRUCTION MATERIAL

Corrosion Resistant Fittings Are Die-Formed. *Heat, Piping & Air Cond*, **19**, No. 7, 180 (1947) July.

New line of Nibcoloy wrought fittings of Inconel, nickel, Monel and stainless steels 304, 316, and 347 are available in 11 types of tees, elbows, reducers, adapters, etc. The fittings are die-formed and are offered in sizes from $\frac{1}{4}$ to 4 in. O.D. A patented lock ring assembly is designed to provide a simple and efficient method of joining with silver brazing or soft soldering (though the joints may also be butt welded). Each fitting has a permanent identification tag so that matching of metallurgical and physical properties of pipe and fittings may be

accomplished at any future date. Mfg. by Northern Indiana Brass Co.—INCO.

(Metals in) Plastic Engineering in 1946. *Modern Plastics*, **24**, No. 5, 137-146 (1947).

Many new aircraft will have flooring made with honeycomb faced with an aluminum alloy skin. In one installation, a 35% saving in weight, with a 30% increase in strength, was effected. Vacuum evaporation is used to apply metallic coatings to plastics. Coatings of aluminum and silver on sheet methyl methacrylate give very good mirror surfaces. The advantages of beryllium copper as a mould material for plastics are given.—MA.

Requirements of Steel for Gas Turbines. H. R. Zschokke & K. H. Niehus, *J. Iron & Steel Inst.*, **156**, Pt. 2, 271-283 (1947) June; *Ibid*, Pt. 3, 385-390 (Nov.).

When testing and evaluating heat-resistant steels for gas turbines used in peace time on land and sea, other criteria are taken into account than in the case of airplane turbines for military aircraft, because in peace-time a life of many years is required, whereas for aircraft turbines a life of a few hundred hours is enough. This difference is important in evaluating creep tests on turbine blade steels. The alternations of structure after long exposure to high temperatures need further exploration, and value of various methods to raise the creep limit must be studied. Fatigue strength and corrosion resistance of the blades and the combustion chamber are also important to the engineer. Requirements are more stringent here than for aircraft turbines, since dif-

Study of the Corrosion of Cast Iron Crucibles Used for Melting Light Alloys. M. Bardot, *Fonte*, 798-810 (1947) Sept. 1.

Bibliographical survey, prepared under auspices of the Centre Technique des Industries de la Fonderie, has been completed and was the subject of a paper presented by P. Bastien and S. Daescher, at 21st Congress de Fonderie, Oct., 1947, which will be published in a later issue of *Fonderie*. 17 ref.—INCO.

Stainless Steels for the Chemical Engineering Industries. I. Berkovitch, *Iron & Steel*, **20**, 648 (1947) Dec.

Reviews paper on the general resistance to corrosion of various commercial stainless steels, by L. Rotherham, presented to the Society of Chemical Industry (Chemical Engineering Group).—BLR.

When and How to Use Cast Iron. T. E. Egan, *Matl. & Meth.*, **26**, 71-75 (1947) Dec.

Describes characteristics of present-day gray iron which make it an engineering material which is selected for its ability to do a job, rather than only because of cheapness, as was once the case.—BLR.

FUNDAMENTALS

Corrosion, Passivity and Passivation from the Point of View of Thermodynamics. M. Pourbaix, Comm. Tech. des Etats et Proprietes de Surface des Metaux Conference, Paris, Oct., 1945. *Journées des Etats de Surface*, publ. by l'Office Professionnel General de la Transformation des Metaux, 251-265 (1946).

By utilizing the laws of thermodynamics, the circumstances of equilibrium of any chemical or electrochemical reaction can be predetermined, if values of free energies (chemical potentials) are known, and thus conditions defined under which passivation (defined as state when metal is covered with protective film), passivity (when surface remains really metallic) or corrosion will prevail. Equilibrium diagrams are given for $\text{Fe-H}_2\text{O}$, $\text{Cr-H}_2\text{O}$, and graphs show the domains of corrosion, passivity and passivation of iron and copper, as well as domains of acidification, alkalization and stability of H_2O in terms of pH and potential. A solution is corroding or not according to whether the amount of iron which it dissolves is more or less than 10^{-6} atomic grams per liter (that is, 0.056 mgr. iron/l.). Experiments which confirm theoretical conclusions are presented and cover behavior of iron 1) when utilized as electrolytic anode, 2) when used as cathode, 3) electrically isolated, in oxygen-free solution, 4) in oxygen-saturated solution and 5) in presence of solutions containing chromates. By superimposing equilibrium diagram of $\text{Fe-H}_2\text{O}$ on that of $\text{Cr-H}_2\text{O}$, circumstances of passivation by chromates are derived. The pH for passivation of solutions containing 3.2g chloride/l. is 12.6. Values for chromate in relation to chloride content are also given. Influence of pH on potential of anode passivation of iron and on current density of this are graphed. Finally an equilibrium diagram shows passivation and corrosion areas and other relations covering behavior of iron in oxygen-saturated solutions of acetic, carbonic, caustic and phosphoric solutions. 15 ref.—INCO.

Metallurgical Factors in the Embrittlement of Welded Plate. R. D. Stout & L. J. McGeady, *Welding J.*, **26**, 683s-692s, (1947) Nov.

Causes of impairment of notch resistance and ductility of structural steel by welding were investigated. Under external loading, cracking is shown to originate in the intergranular structure of the coarse grains in the weld-heated zone. Resistance to crack propagation is strongly and adversely affected by the notch sensitivity of that steel structure which is heated within the critical range of the steel. Metallurgical reasons for this effect are presented. If pretreatment is performed by quenching and drawing or spheroidizing, the sensitivity of the steel to intercritical temperatures is greatly lessened. It is suggested that localized gas-torch postheating may be an easy and practical way of restoring the properties of the welded plate. Besides this, heats of high-tensile steel and performance of E6010 and HTS electrodes were compared, and a simplified specimen-preparation procedure was developed.—BLR.

Phase Contrast in the Photomicrography of Metals. F. W. Cuckow, *Nature*, **159**, No. 4045, 639-640 (1947).

The application of phase-contrast methods to the metallurgical microscope is described and illustrated by reference to photographs of alloy steels heat-treated to show intermediate transformation products. The methods depends on the differences in phase of the light reflected from constituents which lie at different levels in the specimen surface, and gives clear distinctions between constituents which are otherwise difficult to distinguish photographically.—MA.

Investigation of the Structure of Steel by Means of Analysis of Oscillograms. K. M. Bol'shova, *Zavodskaya Laboratoriya Factory Laboratory* (In Russian), **13**, 1079-1086 (1947) Sept.

The work described was undertaken because of the need for closer standardization in the heat treatment of tool steel. Results showed that the above method, which is applicable mainly to the surface layer, proposed by N. C. Akulov in 1934, is satisfactory.—BLR.

GENERAL CORROSION

Protection of Electric Equipment on Ordnance Vehicles Against Corrosion and Rust. Off. Pub. Bd., Report PB. 36,938,

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1945, 17 pp.; *NPVL absts.* No. 121, 62 (1947).

Describes a method for protecting electrical equipment such as generators and starting motors against corrosion. It is intended for electrical equipment that has not been corrosion-proofed in production. The insulating compound specified in this bulletin is air-drying and can be sprayed or brushed on the electrical equipment or applied by dipping.

Corrosion of Metals. *Archiv fur Metallkunde* (In German), 1, No. 6, 249-289 (1947) June.

This issue of the journal consists of papers on the corrosion of metals, as follows: F. Todt, "Influence of the Oxide Film on the Rate of Corrosion, in Particular of Iron" (pp. 249-251); K. Wickert, "New Aspects of the Attack on Metals Resulting from Local Cells" (pp. 251-259); L. W. Haase, "Behavior of Metallic Materials towards very Dilute Aqueous Solutions" (pp. 259-264); V. Cupr, "Electrochemical Study of Metals Protected by Basic Coatings" (pp. 264-267); W. Machu, "Influence of Pickling Inhibitors and Inorganic Substances on the Corrosion of Iron in Warm Water" (pp. 267-270); K. Wickert, "Metallic Corrosion and Catalysis" (pp. 270-275); L. Hertelendi, "The Inhibiting Action of Nicotinic Acid in the Solution of Metals" (pp. 275-278); K. Wickert, "Corrosion and the Periodic System" (pp. 278-281); R. Weiner, "The Corrosion of Silver by Bromine" (pp. 281-284); A. Beerwald, "The Corrosion of Magnesium-Manganese Casting Alloys and Semi-Products" (pp. 284-285); R. Beythien "Corrosion of Phosphated High-Purity Zinc Alloys by Fire-Extinguishing Media" (pp. 286-288); F. Todt, "The Galvanic Protection of Iron Exposed to Sea-Water by Contact with Zinc" (pp. 288-289).—BNF.

Mildew Preventives. Milton A. Lesser, *Soap & San. Chem.*, 23, 119-121+ (1947) Nov.

A review, including many typical recipes. 40 ref.—BLR.

Machining by Erosion. B. R. Lazarenko & N. I. Lazarenko, *Am. Mach.*, 91, 120-121 (1947) Dec. 4.

Describes and diagrams new Russian machine tools which are said to form holes to almost any shape and to dress tools without causing surface flaws by use of a vibrating, but not rotating, spindle to which a tool of almost any desired shape may be attached.—BLR.

The Metallurgist Aids the Chemist. L. Sanderson, *Mach. Lloyd*, 18, No. 24, 103-105 (1946).

Summarizes many war-time developments, including the development of a new gas-turbine alloy containing chromium 33.3 percent, molybdenum 30.8 percent, and iron 35.9 percent. Zinc in contact with steel at high temperature causes rapid corrosion. Pliability of hot-dipped zinc coatings on steel is improved by an initial roughening of the steel surface. A brilliant multi-colored electroplate has been obtained from a solution of 20 g./l. ammonium molybdate with 1 g./l. sodium cyanide. Adhesion of tin bearings is improved by the initial tinning of the steel backing piece with a solid solution of tin-antimony compound in lead, which is capable of dissolving up to 7 percent iron.—MA.

The Place of the Metallurgist in Industry. Sir Arthur Smout, *Metallurgia*, 37, No. 217, 7-10 (1947) Nov.; *Met. Ind.*, 71, Nos. 22 & 23, 439-441, 465-466 (1947) Nov. 28, Dec. 5.

Education and training; function and scope of the metallurgist, including manufacture and production, control, research and development.—BNF.

The Corrosion of Metals with Oxygen Depolarization. N. D. Tomashov (In Russian), p. 258, illustrated, (1947). Moscow and Leningrad: Academy of Sciences of the USSR (17 roubles).

Book summarizes results of a number of years' work by the author on the corrosion of metals. The main divisions of the book are: (1) Theory of the Electrochemical Corrosion of Metals, (2) Theory of Cathodic Processes in the Corrosion of Metals with Oxygen Depolarization, (3) Experimental Study of Various Cathodic Materials, (4) The Effect of the Size, Shape and Position of the Cathodic Surface on the Effectiveness of the Work of the Cathode, and (5) The Application of Polarization Curves to Problems of the Corrosion of Metals. The principal conclusions are given in a seven-page English summary.—MA.

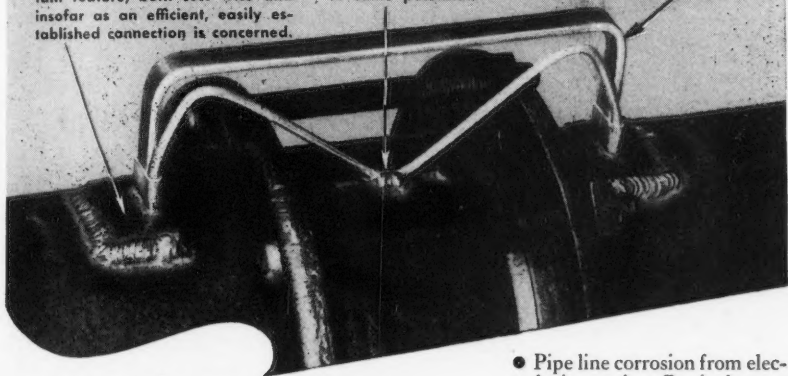
The Metallurgist and Atomic Energy. R. F. Bacher, U. S. Atomic Energy Commission, Paper before ASM, Chicago Mtg., Oct. 23, 1947; *Metal Prog.*, 52, No. 5, 800-802 (1947) Nov.

Most spectacular contribution of metallurgists to development of atomic energy and its application was work on plutonium. Quantity production of uranium

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2. Secondary steel wire shunt can be tack-welded to middle ring of coupling and to follower rings to keep all parts of coupling at same potential.

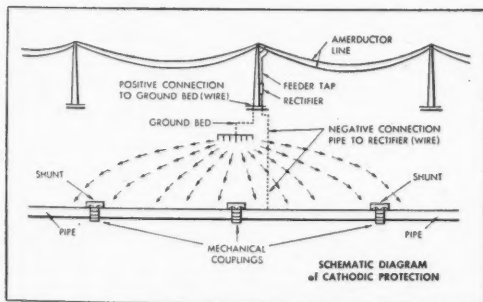
3. Heavy copper bar flash-butt welded to steel terminal gives low resistance connection between two sections of pipe.



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• Pipe line corrosion from electrolysis can be effectively prevented with a set up as shown in the diagram for Cathodic protection.

Shunts and connections of a homemade nature have been used but these are expensive to make in the field and do not lend themselves to efficient and economical installation.

To overcome the many difficulties encountered, engineers at American Steel and Wire Company designed these new pipe coupling shunts, coupon and galvanic anode connectors, and the proper electrical conductors needed for an effective system of Cathodic Protection. Write for complete information to American Steel and Wire Company, Advertising Division, Rockefeller Building, Cleveland, Ohio.

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U-S-S American Pipe Coupling Shunts

was a second. Now atomic energy is helping the metallurgist. Examples are use of radioactive isotopes as tracers to tell how fast metal wears off on high-speed ball bearings and where it goes, and to determine distribution of sulfur between slag and metal in iron production. Separation of stable isotopes such as iron, nickel and copper is now going on at Oak Ridge and these are used also as tracers, especially in the oil industry. Nuclear properties of materials become of paramount importance for use in nuclear reactors which will be used to produce materials with properties not now obtainable and also fissionable materials. Nuclear requirements may be such that it will be necessary to prepare separated isotopes for these materials in sufficient quantity that they may be used as vital constituents in the structure of certain reactors.—INCO.

Preventing Rectifier Corrosion. D. W. Borst, *Coal Age*, 52, 89-93 (1947) Dec.; *Metals Rev.*, 21, No. 1, 12 (1948) Jan.

The types of corrosion encountered with sealed ignitrons, effect of potential difference across piping and its elimination, recommended anti-freezes and corrosion inhibitors, and electrolytic targets are discussed.—INCO.

Primary Causes of Corrosion. *Steel*, 122, No. 2, 89 (1948) Jan. 12.

Primary Causes of Corrosion were discussed in several papers at the recent annual meeting of Societe Francaise de Metallurgie in Paris. U. R. Evans, Cambridge, England, in "Theoretical Aspects of Corrosion and Oxidation" classified reactions on metals as those which develop a film on the metal surface, in which case the reaction slows down with time, and those which do not develop a film, in which case the oxide is soluble and the speed of corrosion practically constant. A good protective film has a high electric resistance. According to M. G. Chaudron (Faculty of Science, Paris) in "Surface Behavior and Actual Physico-Chemical Properties of Metals," the state of a metal surface influences the superficial and even mass properties of the metal. E.g., mechanical polishing, by activating the metal surface, tends to facilitate its reactions with the surrounding atmosphere. A "chemical skin of a varying degree of complexity" is formed, which determines many of the metal's characteristics. In a paper, "The Influence on the Tensile Strength of Solids

of Liquids That do not Have a Noticeable Chemical Reaction," C. Benedicks (Metallographic Inst. of Stockholm) cited experimental evidence showing that the presence of a liquid which wets a metal without showing any chemical action considerably influences the tensile strength of the metal where cracks can develop due to stresses.

Resistance of Metals and Alloys Towards Corrosion. U. R. Evans, *Journées des Etats de Surface*, Paris, 233-234 (1945).

A short general article, drawing attention to the protective effect of oxide skins and the role of oxygen in renewing or repairing these. It is stressed that film breakdown is due less to the direct solution of the film in the corrosive medium than to reduction of the metal ion present in the film to a lower valency state, under conditions of cathodic polarization. The protective character of Al_2O_3 , Fe_2O_3 , and Cr_2O_3 films are compared from the point of view of the stability of the 3-valent state for the metals concerned.—MA.

Iron Oxide Conversion, a Previously Unrecognized Cause of Refractories Destruction. C. Burton Clark & C. L. Thompson, *Ind. Heat.*, 14, 2056 (1947) Dec.

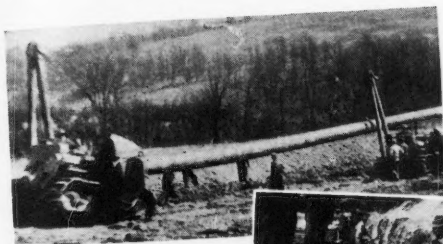
Laboratory experiments have shown that repeated alternate oxidizing and reducing conditions of 2200° and 2400° F., as well as repeated change in temperature above and below 2500° F. in an atmosphere of air, cause a spongy growth in iron oxide. This growth is apparently the result of repeated conversions of one oxide to another, and may have a destructive effect where iron oxide is deposited on furnace refractories.—BLR.

Paints in Railway Service; Some Factors Affecting Their Choice. F. G. Dunkley & D. P. Earp, *J. Oil & Colour Chem. Assoc.*, 30, 391-417 (1947) Oct.

Rather extensive treatment in first part covers surface preparation, methods of application, method of construction and nature of materials, accessibility, function, conditions of service, cleaning and other related topics. Part II gives details of test procedures used by British Railway Company.—BLR.

Roan Antelope Smelter, Northern Rhodesia-TP2249. R. J. Stevens, Roan Antelope Copper Mines, Ltd., Paper before AIME N. Y. Mtg., Feb., 1947; *Metals Tech.*, 14, No. 8, 1-18 (1947) Dec.

Detailed description of equipment and



Left: Oil line,
coated with Reilly
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Right: Gas line,
coated with Reilly
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Left: Water lines,
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smelting operations, as well as operation of steel foundry in which grinding balls and ball mill feed end liners of 1.6-1.8 carbon steel are produced, as well as pouring-plates for blister copper molds made from scrap cast iron charges. Uncommon features of operation are high grade of concentrate treated (50% copper), high flux burden on charge necessary because of deficiency of bases in concentrate and high alumina content of concentrate, frequent necessity of adding coal to furnace charge to control matte grade, and high grade of matte produced. Blister copper shipped is so pure that only one fire refining operation is needed to produce a wirebar with properties comparable to electrolytic copper. Problem of bismuth-control is handled in converters. Water-cooled copper blocks are incorporated in the uptake wall of the furnaces to prevent corrosion of brick and rebate between bricks is filled with ground magnesite to protect suspension pin and lower part of hook from corrosion by concentrate and dust. In converter, cast steel ladles with detachable rings are given a life of 6 years, by welding of circular cast steel disc, 4 in. thick, into bottom when cracking of original bottom or abnormal wear appears. Grinding balls are cast in the steel foundry in two piece low-blister copper molds, which are cast in converter aisle on a cast iron core surrounded by a machined copper mold cap. Steel charge consists of discarded steel railroad sleepers, second hand rails, miscellaneous plant scrap and gates, riser and fins from foundry. No refining of steel is done. The high carbon steel of the balls leads to relative brittleness of ball clusters which permits ease in breaking them apart. Illustrated.—INCO.

INHIBITORS

Corrosion Inhibitor. *Tool Eng.*, 19, No. 5, 68 (1947) Dec.

Steelye 11 for steel and other metals has as an active ingredient, the barium salt of an alicyclic sulfonic acid. It is a thin, dark, liquid having a flash point of about 150° F. and can be applied by dipping, brushing, or spraying, leaving a soft, transparent, coating that can be removed by wiping or degreasing.—INCO.

Vapor Phase Rust Inhibitors. *Prev. Deterioration Abstr.*, 2, No. 4 (1947).

Shell's Vapor Phase Rust Inhibitors, No. 220, diisopropylamine nitrite and No. 260 dicyclohexylamine nitrite were discussed by H. R. Baker, Naval Research Lab., at a Joint Army-Navy Deteriora-

tion Prevention Meeting, (1947) Feb. 6. These compounds, neutral when pure, should be used for maximum effectiveness at a pH of 7.0 to 8.0. For steel, 2 percent of No. 220 is effective in liquid and vapor phase up to 140° F. when dissolved in mixtures of water with ethyl alcohol, methyl alcohol, or Carbide & Carbon Co. Ucon fluids HB series. In the liquid phase, 0.01 percent of No. 220 is effective up to 120° F., and a similar concentration of No. 260 is good up to 140° F. Higher temperatures necessitate higher concentrations. One percent of either compound in distilled water prevents rust in the vapor phase above the water for one week at 100° F. "VPI" compounds may be applied in impregnated crystals, or in crystalline forms for dusting. At extremely low relative humidities they are corrosive to magnesium and zinc and at higher humidities also affect lead and cadmium.

Sodium Nitrite as Inhibitor. *Chem. Trade J. & Chem. Eng.*, 117, 274 (1945), Sept. 7; *Corros. & Matl. Prot.*, 4, No. 5, 21, (1947) Sept.-Oct.

Laboratory tests by the Shell Development Co. have shown sodium nitrite to be a good corrosion inhibitor for water. Under many conditions, it completely suppresses the corrosion of steel. It can completely prevent corrosive attack on steel in sodium chloride and in aqueous alcohol solutions. In those cases where it does not exert an inhibiting effect, it has no adverse effect.—INCO.

Chlorine and Sodium Pentachlorophenate as Fouling Preventives in Sea Water Conduits. H. J. Turner, Jr., D. M. Reynolds & A. C. Redfield, *Ind. & Eng. Chem.*, 40, 450-453, (1948) Mar.

Continuous chlorination with residual concentrations as low as 0.25 ppm prevents attachment and growth of slime bacteria and macroorganisms in sea-water circulating systems. Sodium pentachlorophenate prevents attachment and growth of macroorganisms but is ineffective in eliminating slime when concentrations as low as 1.0 ppm are maintained continuously. Data for various marine animals are tabulated and discussed.—BLR.

Corrosion Inhibitors in Theory and Practice. Robert D. Misch & Hugh J. McDonald, *Wire & Wire Prod.*, 23, 221-226+ (1948) Mar.

Discusses the mechanism of inhibitor action on the basis of present knowledge. Applications of inhibitors are reviewed. 36 ref.—BLR.



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The Pulse Polarizer in Corrosion Research. Glenn A. Marsh, *Corros. & Matl. Prot.*, **5**, No. 1-2, 15-20 (1948) Jan.-Feb.

Describes instrument designed to provide reproducible data on the polarization of metals. Essentially it consists of a high voltage d-c source, a pulse-discharge mechanism, a sensitive polarization detector, and a high-speed recorder. Tells how such data are used to evaluate surface coatings, corrosion inhibitors, relative corrosivity of different chemicals or solutions, and other present and potential uses in corrosion and electrochemistry. 15 ref.—BLR.

Use of Inhibitors in Corrosion Control. Norman Hackerman, *Corrosion*, **4**, 45-46; discussion, 56-60 (1948) Feb.

Describes use of a number of specific materials, to show that the effectiveness of a material as an inhibitor in one instance does not make it generally applicable, and considers several theories of corrosion inhibition—particularly the relation of absorption to such action. 59 ref.—BLR.

Rate of Breakdown and Mechanism of Nitrite Inhibition of Steel Corrosion. Rowena Pyke & Morris Cohen, *J. Electrochem. Soc.*, **93**, 63-78 (1948) Mar.

A study was made of the effect of temperature and concentration on the above. The end breakdown product of nitrite was identified and the effect of ratio of cathodic and anodic areas on consumption of nitrite was determined. Rate of consumption was found to be dependent on rate of steel corrosion. A mechanism of reduction of nitrite by adsorption at anodic areas followed by reduction of cathodic hydrogen to give an adherent protective oxide is proposed.—BLR.

Effect of Inhibitors on the Corrosion of Zinc in Dry-Cell Electrolytes. Clarence K. Morehouse, Walter J. Hamer & George W. Vinal, *J. Res. Natl. Bur. of Stds.*, **40**, 151-161, (1948) Feb.

Deals with a study of substitutes for mercury and chromate films in curtailing corrosion of the zinc anode of LeClanche dry cells at high temperatures. Certain organic compounds and commercial products are found to be effective. However, dry cells made with them did not have the expected increase in shelf-life or electrical output. On the other hand, the paste wall of the dry cell was found to have inhibiting properties. Two active constituents were isolated, and found to

be effective in retarding the corrosion. These materials will increase the capacity of dry cells at moderate temperatures.—BLR.

INSPECTION

X-Ray Gaging of Sheet and Strip Thickness. *Iron Age*, **161**, 69, 127, (1948) Jan. 29.

Describes gage developed by Westinghouse Electric which permits continuous measurement, roll-pressure control and classification of metal sheets and strip. Other thickness-gaging uses are suggested.—BLR.

Thickness Gage. *Electronics*, **20**, No. 12, 218 (1947) Dec.

Steel thickness from 0.125 to 2.250 inches can be determined by a precision instrument comprising a four-electrode probe, battery, and electronic volt-meter. This thickness gage, manufactured by the Scott Electroflux Co. can be used for measuring corrosion and wall thickness from one side of a metallic surface to an accuracy of 3 percent.—INCO.

Electronic Inspection. *Aircraft Prod.*, **10**, 52-54, (1948) Feb.

Describes principles and applications of the Corneliuss comparator for checking structure, composition, flaws, dimensional variations, hardness, surface-finish, comparison, stress-strain analysis, etc.—BLR.

Gamma-Ray Radiography for Inspection Work: A Comparison with X-Ray Technique. J. C. Chaston, *Aircraft Prod.*, **9**, No. 106, 309-311 (1947).

Discusses the use of gamma-ray radiography for inspection work and compares the necessary technique with X-ray technique. Source of gamma-radiation is a radium salt sealed in a thin-walled platinum container. The radium salt slowly decays, emitting X-rays with the subsequent formation of radon gas. Disintegration of the radon with subsequent emission of gamma-rays is briefly described, and some of the outstanding characteristics of gamma-rays—scatter, penetrating power, and photographic contact—are dealt with in some detail. Contrast between flaws and sound metal is less with gamma-rays than with medium-voltage X-rays, but a much wider range of sections can be examined with a single exposure. Important advantages of radiography by gamma-rays are the extreme compactness and portability of the apparatus, the deep penetration obtained, and the clear definition over the whole field of the negative. The construction

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and use of the radium bomb containing the radium salt is fully described, and practical advice is given on routine inspection work.—MA.

Testing Materials for Internal Discontinuities with Supersonic Echoes (Reflectoscope). J. W. Dice, *Ind. Radiography Non-Destructive Test.*, 5, No. 4, 29-33 (1947).

A detailed account of the (Sperry) supersonic Reflectoscope, which utilizes supersonic waves (from 0.5 to 12 Mc/s.) to detect discontinuities in metals. The apparatus permits a penetration in aluminum of 28 ft. (24 ft. in steel).—MA.

Use of "Magnaflux" and "Zyglo" for Non-Destructive Testing. K. E. Glover, *Ind. Radiography Non-Destructive Test.*, 5, No. 4, 41-44 (1947).

A review of the scope and technique of (1) magnetic methods for detecting surface cracks and sub-surface discontinuities in magnetic materials, and (2) the use of fluorescent salt suspensions, in conjunction with viewing by near-ultra-violet light, for the detection of surface discontinuities, including cracks, in both magnetic and non-magnetic materials.—MA.

Determination of the Surface Condition of a Specimen by Stereoscopic Vision, and the Measurement of a Coefficient Relative to the Industrial Use of the Specimen. M. A. Mauzin, *Journées des États de Surface* (Paris), 140-142; discussion 142-143, (1945).

The limitations of the instrumental methods for determining surface contours are discussed, and it is suggested that a more immediate assessment of surface condition, and better correlations with surface properties, follow from stereoscopic, visual, or photographic examination of the surface at high magnifications. A form of apparatus suitable for this purpose is described. The measurement of the frictional properties of surfaces is also suggested as giving a reliable indication of the suitability of the surface finish for many common industrial uses.—MA.

Crack Detection. A. J. Weston, *Metal Ind.*, 72, 108 (1948) Feb. 6.

Use of the chalk test for very fine cracks in light-alloy die castings has not always been satisfactory. Use of Wood's metal impregnation under pressure followed by radiography was also unsatisfactory for very fine cracks on account of

high surface tension. Various other types of substances were also unsuccessfully used before an iodized poppyseed oil sold under the name "Neo-Hydriol" was found to be the ideal medium. Results illustrated.—BLR.

Inspection Methods Using Magnaflux and Zyglo in Production Industries. W. E. Thomas, *Non-Destructive Testing*, 6, 9-14, (1947) Fall.

Describes the above, including practical applications; discusses a few of the general principles which apply in factory inspections and shows specifically how these methods are being applied in Production.—BLR.

The Determination of Pipe Protection by the Continuous Polarity Method. W. E. Huddleston, Huddleston Eng'g Co., Paper before NACE, Ann. Mtg., Chicago, April 7-10, 1947. *Corrosion*, 3, No. 7, 325-330, (1947) July.

Procedure for determining spread, location and removal of anodic areas, and procedure for making repairs are discussed and illustrated. Cases are found in which a well-coated pipeline under cathodic protection is found to be discharging much current within a several hundred foot area. No single point of discharge has been encountered. Other than cases involving components of stray-current electrolysis, the cause of highly anodic points on a pipeline under cathodic protection was not determined. Such anodic points are not attributed to protective equipment or devices or to the composition of the protective coating. Anodic areas can be found by localizing the current discharges to within a quarter-mile section by millivolt drop observations, and then finding exact points by an electronic detector. Continuous polarity is valuable in locating and removing sporadic cases of anodic points that cannot be suppressed by cathodic protection.—INCO.

METAL FAILURE

Examination of the Microstructure of Contaminated and Embrittled Platinum and Platinum-Rhodium Wires. R. C. Jewell, *J. Iron & Steel Inst.*, 155, No. 2, 231-234 (1947).

Results of micrographic and spectrographic examination of (a) the wires examined by Manterfield, (b) the wire accidentally contaminated by quenching oil and examined by Goldschmidt and Land, and (c) the service failure referred to by Goldschmidt and Land. The failure of wire (a) was due to severe attack by

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silicon (greatest for the platinum-rhodium wire), a brittle eutectic being formed. The silicide phase in the platinum-rhodium wire was microscopically distinguishable from that formed in the pure platinum wire, showing more relief and a bluish tinge, and exhibiting considerable segregation. These two constituents are respectively the "R" and "P" phases of Goldschmidt and Land. Contamination of wires (b) and (c) was similar, taking the form of intercrystalline attack; similar unidentifiable constituents were present in both instances (probably the constituent "Q" referred to by Goldschmidt and Land).—MA.

The Corrosion and Application of Alloy Steels at High Temperature Under Alternating Oxidizing and Carburizing Conditions. H. K. Ihrig, Globe Steel Tubes Co., Paper before ASM Los Angeles Chapter, *ASM Rev.*, **20**, No. 6, 39 (1947) June.

Results of experiments involving a pilot plant for dehydrogenation of butane to butylene, in which tubes of various compositions were installed, are reported. It was found that iron oxide contamination of catalyst occurred at lower temperatures after inside surfaces of tubes had been carburized during alternate cycle. Use of chromium H.R. steels proved best solution. Type 446 with 0.1 nitrogen were used for reactor tubes. Sulfur was added to feed stock because it was found that sulfur pick-up by metal in tubes tended to counteract the injurious effect of carburizing. An ingenious annealing arrangement permitted annealing of the tubes, charged with catalytic mixture of chromium and vanadium oxides, without removal from installation. A large production plant was built in England patterned after the pilot plant and after 2½ years of continuous operation supplying high-octane gasoline, the reactor tubes were found to be in excellent condition.—INCO.

Preferred Orientations in Drawn and Annealed 70-30 Alpha Brass Tubes—TP-2245. W. R. Hibbard, Jr., Yale Univ., Paper before AIME Chicago Mtg., Oct., 1947, *Metals Tech.*, **14**, No. 6, 1-4 (1947) Sept.

Preferred orientations in drawn 70-30 alpha brass tubing were rationalized on the basis of a double texture with the (111) pole and the (100) pole parallel to the drawing direction and a random orientation about these directions as an axis. This texture is similar to the fiber found in drawn alpha brass wire. Partially

developed textures were found at 24.5 percent reduction in area and were fully developed at 43.6 percent reduction in area. Annealing textures were found to be partly randomized variations of the drawing texture. Hard drawn tubes with well developed textures did not crack when subjected to the standard mercurous nitrate test in spite of heavy reductions in diameter thought to be capable of causing failure. On the basis of this and other evidence (including that of Snoek on iron-nickel alloys) some speculation is presented as to the role of preferred orientations in reducing tendency of metals toward intergranular cracking of the mercuric type. 12 ref.—INCO.

General Corrosion and Stress-Corrosion of Spot-Welded Magnesium Alloy Sheet. W. F. Hess, T. B. Cameron, D. J. Ashcraft & R. A. Wyant, *Welding J.*, **26**, No. 9, 539-544s (1947) Sept.

Author describes stress corrosion tests on two spot-welded magnesium alloys with 6% aluminum, 1% zinc and with 3% aluminum, 1% zinc respectively; the former alloy was the more susceptible. The heat treatments recommended for improving stress-corrosion resistance of magnesium-alloy sheet were not found effective with the welds, whether applied before or after welding; pre-stressing with 75% of the shear strength for 100 hours raised stress necessary for stress-corrosion. Cracking always starts in heat-affected zone.—BNF.

Graphitization of Piping. Progress Report No. 6 by Joint EEL-AEIC Subcommittee. L. E. Hankison, T. E. Purcell, A. D. Bailey & S. Crocker, *Heat., Piping & Air Cond.*, **19**, No. 7, 72-75 (1947) July.

A commercial steel can now be specified that it will resist the usual graphitization process in present power plant operations. Deoxidation practice can be handled and by the use of at least one alloying element chromium—a way is provided for removing any restrictions on that practice. Such a steel can be welded, fabricated, and installed in power stations by conventional methods. By means of kinetic methods of following the course of graphitization in selected samples, the effects of the more important factors of graphitization can be handled on a quantitative basis. But the question of steel for steam lines is still in a state of flux. The power stations are pressing for higher operating temperatures of 1000° F or even 1050° F. A single high temperature steel is desired for tempera-

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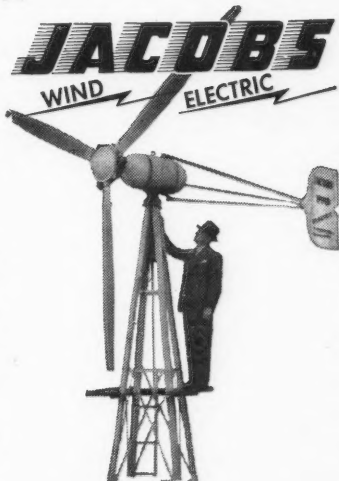
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tures up to 950° or 1000° F. Kinetic studies show that temperatures of 1000° F or more mean about a five fold increase in the rate of graphitization over 900° F. Further study is also necessary for the use of molybdenum-titanium and molybdenum-vanadium steels.—INCO.

Report of Committee A-5 on Corrosion of Iron and Steel. *ASTM Preprint*, 4, 15 pp. (1947).

Includes proposed tentative specifications for long terme iron or steel sheets and proposed tentative test method for weight and composition of coatings on long terme sheets by the triple-spot test.—BLR.

Corrosion of Copper Alloys by Minor Constituents. A. W. Tracey, Amer. Brass Co., Paper before AIME, Boston Chap. of Inst. of Metals Div, 1st Ann. Reg. Conf. on Technol. of Metals, 1947; *Ind. Heat.*, 14, No. 8, 1284 (1947) Aug.

When copper alloys containing small amounts of arsenic, silver, phosphorous or nickel are exposed to industrial, marine or rural atmospheres, they appear to corrode at practically the same rate, regardless of the atmosphere in which they have been placed. As it appears to expedite the formation of the desirable green patina on exposed copper. It also affects the rate of corrosion of copper exposed to sea water. The addition of arsenic, antimony or phosphorous to admiralty brass or aluminum brass does not have any significant effect on the resistance of these alloys to impingement corrosion, pitting, stress corrosion cracking or corrosion fatigue, in sea waters. The addition of 0.5 iron to 70-30 type copper-nickel in condenser tubes, increases its resistance to pitting and impingement corrosion.—INCO.

Carbides, Nitrides, and Porosity in Aluminum (Alloys). Davidlee Von Ludwig, *Iron Age*, 160, No. 21, 73-78, 141 (1947).

Points out that carbides and nitrides are the chief major contaminants in aluminum alloys and questions the suggestion that hydrogen is the primary cause of porosity in these alloys. He discusses the chemical reactions involving carbon and nitrogen that take place and the conditions under which they tend to cause a reduction in the physical properties. He gives results of an investigation that indicate the lack of correlation between strength properties and the conventional X-ray examination technique, and emphasizes the lack of satisfactory

methods for the isolation and identification of minute amounts of active non-metallic constituents.—MA.

Hydrogen in Steel Manufacture. C. Sykes, H. H. Burton & C. C. Gegg, *J. Iron & Steel Inst.*, 156, Pt. 2, 155-180 (1947) June; Pt. 3, 377-381 (Nov.) *Iron & Steel*, 20, 511-598 (1947) Nov. 20.

Determinations were made of hydrogen in plain carbon and alloy steels, including nickel, chromium-nickel, and stainless steels (18-8), in the electric-arc and open-hearth furnace, and in ingots, billets, and forgings. Experiments on semi-finished products indicated that ductility is reduced with H₂ in excess of 2 cc/100 g. A study of the effects of various heat-treatments on H₂ contents and susceptibility showed that high H₂ contents do not automatically lead to hair-line cracks. No conclusive evidence was obtained on the question of segregation, although some alloy-steel ingots and forgings showed wide variations in H₂ content. Data on permeability and solubility were used to calculate values for the diffusivity of H₂ which made possible the prediction of the rate of loss of H₂ from steels at temperatures down to 400° C, at high H₂ concentrations. Results are discussed in relation to theories put forward by other workers on the subjects of H₂ in steel and hair-line-crack formation. 15 refs.—INCO.

The Heat Treatment and Properties of Some Beryllium-Nickel Alloys. W. L. Williams, U. S. Naval Eng. Expt. Sta., Paper before ASM, 29th Ann. Conv., Chicago, Oct. 18-24, 1947; *ASM Preprint* No. 11, 13 pp. (1947).

With strip material 0.012 inch thick, studies were made on the effects of time and temperature on the resulting precipitation hardness of a 2.07% beryllium-nickel alloy of commercial purity. Amount of cold working prior to aging, as well as recrystallization at some of the aging temperatures, are shown to exert considerable influence on the locations and shapes of time-hardness diagrams at various temperatures. Hardness above 500 Brinell could be attained within a few hours. Information gained served as a basis for heat treatment of a cold-rolled 13/16-inch diameter bar containing 1.62 beryllium. Specimens from this material were tested in the full-hard condition for tensile and impact properties, corrosion resistance in salt water, and fatigue strength in air and under the simultaneous influence of cyclic stress and corrosion.—INCO.

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Bibliography on the Fatigue Properties of Cast Iron. G. R. Woodward, *Bull. Brit. Cast Iron Res. Assoc.*, **9**, 59-63 (1947) Nov. 54 ref.—BLR.

Stress-Corrosion Cracking of Steels. W. P. Rees, *Eng.*, **164**, 489-490 (1947) Nov. 21.

Condensed from "Note on Stress-Corrosion Cracking of Steels in the Presence of Sulfur Compounds," presented at the Symposium on Internal Stresses in Metals and Alloys, London, Oct. 15-16, 1947. Discusses several cases of stress-corrosion cracking upon exposure to media containing sulfur compounds: first in stainless-steel filter wire used in a crude-petroleum pipeline; second, in flapper-valve plates of an air compressor; third, of alloy-steel cylinders for gas storage. Each of these cases were thoroughly investigated.—BLR.

Fracture of Platinum and Platinum-13% Rhodium Wires Used in the Immersion Thermocouple. L. Reeve & A. Howard, *J. Iron & Steel Inst.*, **155**, No. 2, 216-220 (1947).

The intercrystalline attack commonly experienced by wires in the Schofield-Grace immersion thermocouple was investigated by heating specimens of platinum-rhodium wire in the presence of oil, in a graphite block, the wires being placed in a silica insulator. Attack was found to be rapid above 1200° C., and a standard test was evolved in which specimens $\frac{3}{4}$ in. long were heated at 1400° C. for 15 min. in the presence of 0.05 c.c. oil, of sulfur content 0.2%. Specimens of wire in the fully cold-worked, partially annealed, and fully annealed states were examined, and it was found, by subsequent micro-examination, that the partially annealed wires were most susceptible to attack, and also showed more marked grain coarsening. A further observation was that, in the presence of the silica insulator, swelling frequently occurred at the portion of the wire just leaving the insulator; maximum attack was found to have occurred at this point. Spectrographic analysis showed the presence of the following elements in the contaminated wires: copper, silicon, manganese, nickel, iron. The conclusions of Chaston et al., that contamination is caused by the co-presence of sulphur and silica, was confirmed by substituting an alumina insulator for the silica one, and by replacing the oil by flowers of sulphur or by liquid paraffin. Attack was only observed with those combinations of materials containing both sulphur and silica.

Oil tests carried out on pure platinum revealed a similar kind of intercrystalline attack. It was found that, in practice, attack could be prevented by baking the iron protection tubes at a dull-red heat in the presence of a current of air.—MA.

Hydrogen Attack on Metals at High Temperatures and Pressures. J. Schuyten, *Corros. & Matl. Prot.*, **4**, No. 5, 13-18 (1947) Sept.-Oct.

A survey of knowledge (with a select bibliography of 27 ref.). Mainly deals with steels.—BNF.

Hydrogen in Steel. J. H. Andrew & others, *Iron & Steel*, **20**, 580-590; discussion, 622-625 (1947) Nov. 20.

Gives results of an extensive investigation of the relationship between evolution of hydrogen and transformation characteristics of the steel as well as the occurrence of defects such as cracks, flakes, and "fisheyes." Effect on mechanical properties is also covered.—BLR.

The Evolution and Absorption of Hydrogen by Steel in Industrial Reheating Furnaces. J. Cameron, *J. Iron & Steel Inst.*, **157**, 609-615 (1947) Dec.

The influence of reheating-furnace atmospheres on the hydrogen content of steel ingots is discussed from the theoretical standpoint. The hydrogen content of furnace atmospheres is calculated for a variety of fuels and for different conditions of humidity and combustion, and it is shown that it is negligible for all practical conditions of humidity and combustion. The possibility of local concentrations of hydrogen caused by the action of water vapor on iron is considered, and they are shown to be not likely to exceed 2%. The effect of such small concentrations on the equilibrium hydrogen content of the steel and also on the removal or absorption from steels not in equilibrium was examined.—BLR.

Embrittlement of Platinum/Platinum-Rhodium Thermocouples. J. C. Chaston, R. A. Edwards & F. M. Lever, *J. Iron & Steel Inst.*, **155**, No. 2, 229-231 (1947).

Authors describe tests in which pure platinum and platinum-13% rhodium wires were heated in contact with carbon, sulphurous vapors, and hydrocarbon vapors [(a) xylol and (b) white spirit]. None of these substances gave rise to embrittlement when employed alone, but severe attack occurred when sulphur and carbon were present simultaneously at

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1200° C. and above. No attack occurred at 1100° C. or below. Chemical analysis of the attacked wires revealed the presence of silicon, but no carbon or sulphur. The explanation advanced is that the sulphur combines with the silicon in the refractory of the furnace lining, forming volatile SiS_2 which attacks the platinum; the presence of carbon is necessary to catalyze this reaction. This explanation was confirmed by substituting fused alumina for the siliceous furnace lining, when no attack occurred.—MA.

The Role of Chemical Reactions in the Phenomena of Rubbing and Wear. C. H. Desch, *Journées des États de Surface*, Paris, 235-236 (1945).

REFINERY CORROSION

New Solutizer Unit Has Unique Features for Disulfide Removal and Regeneration. *Petro. Processing*, 2, 965-966 (1947) Dec.

Describes and diagrams Tannin Solutizer unit recently placed in operation at Cities Service Oil Co.'s Ponca City Okla. refinery.—BLR.

Sour Crudes—Equipment Protection. E. Q. Camp, Humble Oil & Refg. Co., Preprint, API Div. of Refg. 27th Annual Meeting, Chicago, Nov. 11, 1947. *API Preprint*, 14 pp. (1947) Nov. 11; *Oil & Gas J.*, 46, No. 29, 68+ (1947) Nov. 22; *Ibid.*, Pt. 2, No. 30, 83-7 (1947) Nov. 29; *Petro. Refiner*, 26, 796-807 (1947) Dec.; *Corrosion*, 4, No. 7, 371-398, (1948) Aug.

Major corrosion problems experienced in processing sour crudes at the Baytown refinery of Humble Oil & Refining Co. are discussed. Low-temperature corrosion (below 500° F.) occurs in the storage, transportation and distillation of crudes and is primarily due to the presence of hydrogen sulfide, hydrochloric acid water, oxygen and carbon dioxide. Gunitite coatings are most satisfactory for protecting tanks, but coatings of paint and plastics, heavier steel construction, use of aluminum or galvanized steel roofs, maintenance of a protective oil film on the underside of the roofs and caustic washing of distillates are helpful. Caustic or ammonia injections, gunitite linings and corrosion resistant alloys are used to protect distillation equipment. High temperature corrosion, due to sulfur compounds, naphthenic acids, temperature and turbulence, is predominant in cracking operations. The addition of 0.05-0.5% by weight of sulfur (as free sulfur, butyl mercaptan, or carbon disulfide) to naphtha

from Refugio crude inhibits the corrosion of 18-8 alloy and essentially eliminates coke deposition on the alloy. 27 ref.

SURFACE PREPARATION

The Possibilities and Limitations of Electrolytic Polishing—A Survey of the Present Position. A. F. Brockington, *Sheet Metal Ind.*, 24, No. 243, 1414-1416, (1947) July.

Mop and electrolytic polishing, appearance of surface, cost considerations and metal removal are discussed. Grained appearance varies according to composition and physical state of the metal before treatment, and is influenced by surface conditions. A smooth matt surface, such as a dull nickel electrodeposit on a polished article, can be given a high specular brilliancy by electro-brightening, and the finish will have little grain compared with that of the average stainless steel of nickel silver article brightened by the same process. In electro-brightening, the amount of metal dissolved is usually about 0.0005-0.002 inch, the dissolution rate of stainless steel in an electrolyte of mixed sulfuric and phosphoric acids being about 0.001 inch in 10 minutes when the bath is operated at a current density of 300 amps. sq. ft. As much as 0.00015 in. is dissolved in 1 min. on electro-brightening dull nickel deposits in sulfuric acid. This reduced the thickness of the nickel deposit and consequently the degree of protection afforded to the article.—INCO.

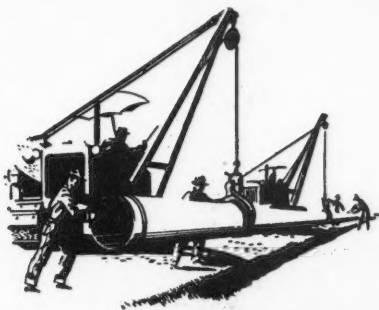
Treatments for Metal Surfaces Prior to Painting. E. F. Hickson & W. C. Porter, *Prod. Eng.*, 18, No. 8, 128-30 (1947) Aug.; *Austin Tech. News*, No. 207 (1947).

Thorough cleaning and the use of a chemical wash solution, or an electrochemical treatment, are pre-requisites to obtaining and maintaining a continuous paint film on metal. Cleaning treatments used for the common metals and alloys are discussed, with details of recommended solutions. A complete spray-chamber process for cleaning and chemically treating either steel, aluminum or zinc is illustrated.—RPI.

Fundamental Aspects of Metal Cleaning. Jay C. Harris, *Am. Ceramic Soc. Bull.*, 26, 389-392, (1947) Dec. 15.

Forces involved in the attraction between the metal surface and the various contaminants encountered are discussed, means for "neutralization" of these forces, and materials and methods with which to accomplish cleaning are described.—BLR.

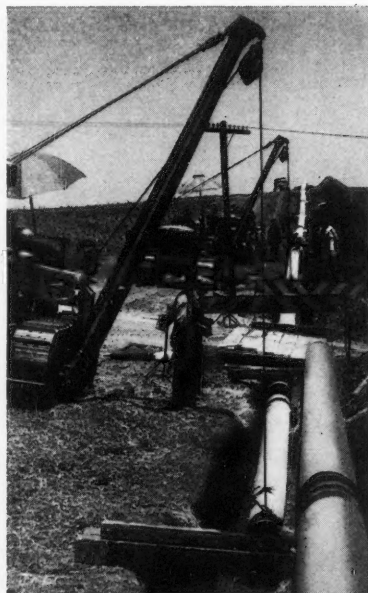
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Report on the Evaluation of Surface Treatment of Steel Prior to Painting. Arnold J. Eickhoff, *ASTM Bull.*, 77-80, (1948) Jan.

This is the final report of outdoor-exposure tests conducted by Sub-committee of ASTM Committee D-1 on Paint, Varnish, Lacquer and Related Products to determine the effect of cold phosphate-phosphoric acid pretreatments of steel surfaces which were subsequently painted. Results are tabulated, charted, and discussed.—BLR.

Cleaning Metal for Painting. F. L. Kinrab, *Ind. Fin.*, 23, No. 11, 55-6 (1947).

Describes some important points on cleaning metal surfaces before painting and also the equipment and materials used.—RPI.

Shot-Peening Increases Life of Machinery. Parts I & II. R. B. Huyett, Pangborn Corp., *Steel Proc.*, 33, No. 9, 553-557, 573, (1947) Sept.; No. 10, 609-613+ (1947) Oct.

Fullest details for shot peening machinery parts are given. SAE standard peening shot numbers are tabulated. Examples which give part, shot used, test strip reading, and increase in life for specific part are briefly described. Valve rocker arms for aircraft engines had life increase of 1400%; connecting rods, 106%; automobile coil springs, 2000 to 5500%; leaf springs, 100 to 600%; aircraft engine crank cases 30%; automobile steering knuckles over 400%. Use of the Almen test gauge and test strip is described in detail. This is based on the fact that a strip of steel of known quality and fixed size when peened on one surface will respond in the form of an arc longitudinally and more or less transversely. The measurement of the arc height indicates the peen intensity. Removal of cracked shot is discussed. Second installment discusses storage bins for automatic continuous replenishing of shot, shot projectors, systems of air blast, shot, and finally a shot breakdown tester.—INCO.

Surface Preparation of Semi-Finished Tool Steel. S. F. Magis, *Iron & Steel Engr.*, 24, 78-91; discussion, 91, (1947) Nov.

Reviews chipping, grinding, and some of the metallurgical methods employed in maintaining the surface quality of semi-finished tool steel for rolling and forgings. Illustrated.—BLR.

A New Surface Treatment for Magnesium. A. L. Kohl & H. Waterman, *Iron Age*, 161, No. 4, 50-55 (1948) Jan. 22.

A new surface treatment for magnesium has been developed which consists in anodizing the parts in a hot saturated sodium carbonate solution. Photographic grade or carbon-phosphorus sodium carbonate monohydrate is recommended. Bath temperature should be maintained at about 198° F. (92° C) + (9°) and the voltage should be about 115. Higher voltage will produce more corrosion-resistant coatings but if too high, sparking across the film and subsequent pitting may result. The cathode may be any metal not attacked by sodium carbonate. Stainless steel, Monel metal and copper have been used satisfactorily. The coating produced by this treatment is a hard, white crystalline material, similar in composition to a form of basic magnesium carbonate. Repeated salt spray tests showed the treatment to be greatly superior to the acid dichromate treatment. Besides corrosion resistance, the coating offers considerable abrasion resistance and makes a good base for paint.—ALL.

The Surface Preparation of Aluminum for Paint Systems. *Aluminum and the Non-Ferrous Rev.*, 12, 54, 56 (1947) July-Sept. Condensed from brochure issued by Northern Aluminum Company, Ltd., Banbury, Oxon, Eng.—BLR.

Anodizing of Aluminum. *Light Metal Age*, 5, No. 10, 22-24 (1947).

A general survey of processes.—MA.

Surface Preparation for Metal Spraying (Zinc and Aluminum). *Machinist*, (Eur. Ed.), 91, No. 8, 235-238 (1947).

The necessity for proper surface preparation to secure adhesion in metal spraying, the metallurgical considerations involved, and the methods of preparation that can be used are described. The metals primarily concerned are zinc and aluminum; cadmium has somewhat limited applications on account of its high cost.—MA.

The Dichromate Treatment for Magnesium. *Prod. Fin.*, 11, No. 7, 96, 98 (1947).

A brief outline of a dichromate treatment for magnesium prior to painting. Operating details given.—MA.

Uses of Shot Peening Other Than for Fatigue Durability. L. J. Wieschhaus, Am. Wheelabrator & Equipment Corp., *Prod. Eng.*, 18, No. 8, 122-127 (1947) Aug.

Use of shot peening to inhibit stress corrosion cracking to reduce porosity in metal parts subjected to pneumatic and



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hydraulic pressures, to test the adherence of silver plate, to improve the lubricating properties of plain bearings and to replace polishing operations is discussed. Since magnesium alloys have a tendency to crack under stress in a corrosive atmosphere, certain magnesium alloys were the first to be tested under accelerated conditions. Later brass, mild steel, and stainless steel were tested. Table shows stress corrosion cracking of peened and nonpeened specimens of magnesium sheet. Not all attempts to inhibit stress corrosion cracking by shot peening have been successful, and a table contains data from a series of unfavorable tests. A chart showing matter available. In NA-115 reports exclusive of case histories on fatigue durability is given.—INCO.

Some Aspects of the Problem of Corrosion Tests in the Laboratory. Mlle. Goldowsky, Scientific Collaborator, *French Air Ministry Paper, ABEM* (1939) Jan. 25, *Bull. de la Soc. Royale Belge des Ingenieurs et des Industriels* No. 9, 16 pp. (1939).

The difficulty involved in testing metals for their behavior against corrosion in actual performance is described. It is important that one knows the uses for the metal to be tested, the nature of attacking medium and the type of corrosion encountered. The actions of the air, sea water, and gasoline on the metals are given with graphs showing the corrosion of Duralumin by sea water as a function of the time during different seasons, and the loss of weight of Duralumin in a 3% sodium chloride solution in the presence of different concentrations of various salts. The effect of the corrosion on the mechanical properties, such as elongation and resistance to rupture, of light alloys are given. The influx of the conditions of construction, such as whether the metal is in sheet form or rolled, welded, by blowpipe or electrically, or riveted as well as the protection possible are discussed.

Anodizing and Its Uses in Engine Construction. N. D. Tomashov, *Vestn. Inzhn. Tekhn.*, (In Russian) No. 2, 59-65 (1946); (English Translation) *Light Metals*, 9, No. 103, 429-438 (1946).

Attention is devoted to the practice and control of anodizing, with special reference to the production of films of value in the development of improved service characteristics in internal-combustion engines. The use of anodic films on pistons, cylinder-heads, cylinders, and bearing and other sliding parts is discussed.—MA.

Determination of Roughness Profiles by the Methods of "Longitudinal Points" and by Interferences. Mlle. F. Flamant & M. A. Arnulf, *Journées des Etats de Surface*, Paris, 110-116; discussion, 116 (1945).

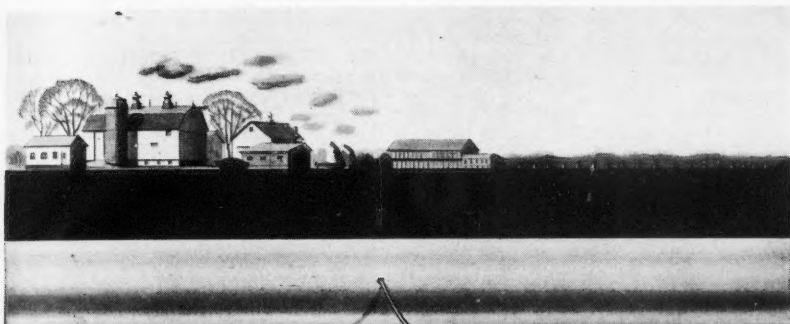
Surfaces obtained by various processes were examined by means of apparatus developed at the Optical Institute. The microscopic and interferometric techniques were used, and are discussed in so far as they affect the measurement of irregularities in the range of 1 mm. to $1/10\mu$. Irregularities in surfaces prepared by planing depend markedly on the type of tool used, and are sharp pointed. Milling, however, gives a more rounded profile, with plateaus instead of peaks. Grinding leads to a very irregular surface with sharp points and deep pits. Typical profiles are reproduced, together with similar recordings from surfaces prepared by fine grindings, by mechanical polishing, and by electrolytic polishing. Corresponding micrographs given, and results discussed.—MA.

Extent and Nature of Roughness on the Surfaces of Electrolytically Polished Copper. Henri Frisby, *Compt. rend.*, 224, No. 13, 1003-1005 (1947).

It is already known that a film of oxide is present on the surface of copper specimens that have been electrolytically polished, and the author undertook experiments to determine if this film is formed during or immediately after the polishing operation. A single-crystal block of copper was cleaned in nitric-acetic acid, lightly oxidized by boiling in water, cooled in air, and examined by X-rays. This showed the presence of the elementary cube of cuprous oxide. The same specimen was then electrolytically polished, washed in distilled water, and left in contact with air for two minutes. Electronic examination indicated the presence of a film of the cuprous oxide similar to that described above. The experiment was then repeated with decreasing time of contact between the wet specimen and the air, and the resulting diagram was neither that of the cleaned nor the oxidized surface. The author considers that it represents the true state of the surface of the copper as it leaves the polishing bath—a surface of metallic copper of which the roughness has been reduced by some fifty times. This surface appears to be very easily oxidizable.—MA.

Review of Recent Work Concerning the Measurement of the Roughness of Surfaces. C. Timms, *Journées des Etats de Surface*, Paris, 117-123 (1945).

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Magnesium

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made, chiefly in Great Britain, in the development of instruments of various types for measurement of surface irregularities. The characteristics of several typical types of machine are described. The problems connected with specification are dealt with, and the author points out that the geometrical aspects must be adequately correlated with the physical aspects if the essential qualities of a surface are to be assessed. Typical records of surface irregularities are reproduced.—MA.

Corrosion Fatigue. G. T. Dunkley, *Mech. World*, 122, No. 3160, 137-141 (1947).

An elementary discussion of the mechanism of corrosion fatigue and of the corrosion-fatigue properties of ferrous and non-ferrous alloys; means of minimizing corrosion-fatigue failures are described.—MA.

Methods for the Non-Destructive Determination of the Loss in Tensile Strength and Ductility (of Light Alloys) by Local and Intercrystalline Corrosion. W. Ehrenberg, *Korros. u. Metallschutz*, 17, No. 1, 19-21 (1941).

Specimens of Dural, Hydronalium, Electron (magnesium-aluminum and magnesium-manganese alloys), and pure aluminum, with and without artificial aging, were subjected to spray, alternating-, and total-immersion tests at 25° C. in solutions of 3% sodium-chloride, 0.1% hydrogen peroxide, 3% sodium chloride, 1% hydrochloric acid, or 0.6% sodium chloride, 0.1% hydrogen peroxide for periods between one-half hour and one day. Measurements were made, at intervals, of the electrical conductivity, extent of surface attack, and damping capacity, and the results of these non-destructive tests were compared with those obtained from measurements of ductility and tensile strength at the end of the test. Empirical relationships are derived by which the decrease in tensile properties can be calculated from the non-destructive test measurements, both in the case of surface attack and intercrystalline corrosion.—MA.

Magnesium Alloys: (Effect of) Small Calcium Additions. Marvin E. Gantz, *Am. Foundryman*, 11, No. 3, 33-38 (1947).

Author reports that when calcium is employed in contents of 0.1-0.2%, the hot-rolling characteristics of such alloys as AZ31X and M1 are improved to such a degree that it is possible to conduct the direct rolling of sheet from sheet ingots. In addition, the mechanical properties of the sheet are enhanced. Microporosity in castings in such alloys as AZ92 and AZ63

is reduced by the addition of 0.5% of calcium. This calcium content also decreases the time required for satisfactory solution treatment, and eliminates the necessity for preheating cycles in the solution treatment of castings of the magnesium-aluminum-zinc type. Calcium additions reduce the oxidation rate of molten alloys, possibly by virtue of the formation of a partially protective film on the exposed surface of the molten alloy. The incidence of hot cracks in fine-grained castings in certain magnesium alloys (e.g., AZ92) is reduced by calcium additions. One of the most serious objections to the use of calcium additions is its apparent tendency to form skins in castings. This defect, however, may be partially overcome by modification of the method of gating, so as to reduce turbulence.—MA.

Lead-Base Babbitt Alloys. I.-Physical and Corrosion Properties. II.-Fatigue and Wear Properties. Henry P. George, *Prod. Eng.*, 18, No. 5, 118-121; *Ibid*, No. 6, 138-141 (1947).

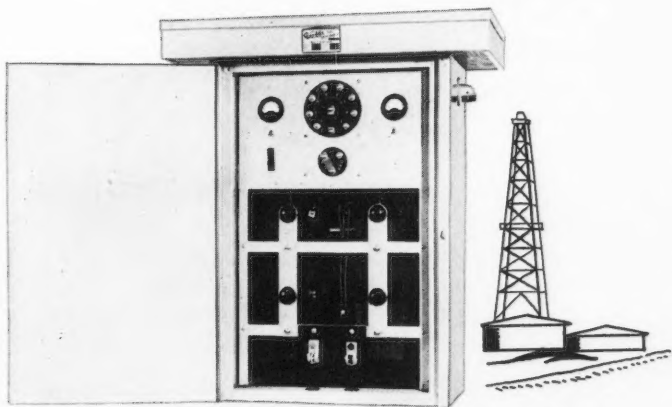
(I.-) Ten lead-base alloys were tested and compared with a tin base alloy (antimony 7.5%, copper 3.5%, tin balance) used as a reference. The composition of the lead alloys varied from 0.75-11% tin, 8-15% antimony, 0.2-2% copper, and 0.2-3% arsenic, the balance being lead. Typical microstructures of the alloys show a duplex structure with hard intermetallic compounds and softer phases, except for a straight lead-tin alloy (tin 3.5%). A comprehensive table gives some of the most important physical properties, and it appears that the liquidus temp. of the lead alloys is generally lower than that of the reference tin alloy, while the solidus temp. is higher. There is no significant difference in the coeff. of friction, and no significant change in weight or visible evidence of corrosion was noted in any of the alloys after immersion at 300° F. (150° C.) for 6 weeks in unagitated oil. Several of the lead-base alloys are softer at room temp. than the tin-base reference alloy, although at 250° F. (122° C.) the difference tends to disappear. Other properties such as yield strength, ultimate compressive strength, dynamic compression, distortion of Babbitt lining under impact, creep under compression, and rate of contraction under creep compressive tests are tabulated. (II.-) The load-carrying ability, as bearings, of the lead-base alloys were determined in a rotational wear test. Loads were applied to the bushing in increasing increments through a collar by a calibrated helical spring. Each increment of load was carried for 24



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hours before the next increase was made. Under this test, none of the lead-base alloys supported as much load as the tin-base reference alloy. All the lead-base alloys showed better resistance to the development of cracks than the tin-base reference alloy. Wear-fatigue tests were performed in the device that simulated in accelerated form the conditions that lead to failure of automotive bearings. The specimens were placed in a centrifugal bearing fatigue-testing machine, in which a rotating load simulated the loading of a main bearing. In the majority of the runs, the rod (upper) bearing was damaged more than the red cap (lower bearing), and in some instances small areas were surrounded completely by fatigue cracks.—MA.

UNDERGROUND CORROSION

Protection of Steel Pipes by Bituminous Materials. E. Fleischmann, *Gas u. Wasser-fach*, 84, No. 31, 437-441, (1941); *Peint. Pig. Vernis*, 17, No. 8, 578, (1942).

A distinction is drawn between pipes used for gas or for water. In the first case, only a thin coat of linseed oil, bitumen or tar is required, sufficient to protect the piping during its installation. In

the second, coal tar products must be avoided owing to the danger of contaminating the water.—RPI.

Anaerobic Corrosion of Buried Iron Pipes. O. B. Wilson, *Water & Water Eng.*, 48, 594-98 (1945); abst. *Prev. Deterioration Abst.*, 3, No. 6 Met 71 G-552 (1947).

The activity of sulfate-reducing bacteria increases in the presence of organic matter found in soil. In order to prevent reaction of the hydrogen sulfide formed with ferrous ions going into solution, iron pipes should be adequately protected with proper coating and placed in minimum contact with organic matter. Soil tests for sulfate-reducing bacteria can be made by the use of a pH indicator. In locating this type of corrosion there are two deciding factors: (1) the earth must be water-saturated or airtight; and (2) the pH of the soil water must be approximately 7.0 ± 0.8 , as sulfate-reducing bacteria are active in either a neutral or slightly alkaline soil.

Tests, Properties of Corrosion-Preventive Lubricants for Lead-Sheathed Cables in Underground Ducts—A Discussion.



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Howard S. Phelps & Frank Kahn, *Corrosion*, 4, 37-44, (1948) Feb.

Describes desirable specifications for the above, lubricants and some special test procedures developed by Philadelphia Electric Co. for their evaluation. Also describes method of application.—BLR.

WATER CORROSION

Turbine Deposits. L. A. Lurkhardt, Allis-Chalmers Mfg. Co., Paper before Am. Pulp & Paper Mill Supts., Chicago, *Paper Tr. J.*, 124, No. 22, 86-88, (1947) May 29.

During the past six years the Water-Conditioning Dept. of Allis-Chalmers has been using X-ray diffraction technique to study the steam turbine blade deposits in 200 samples from 27 power plants. Chemical analyses are not sufficient, and fail to distinguish between several forms of silica occurring. Deposits are classified as: 1) corrosion or erosion material, 2) water insoluble compounds of calcium and magnesium, and 3) silica, silicates and water soluble compounds. Data are tabulated. A summary is made of relations so far found between boiler pressures and turbine deposit composition. Relation of boiler water composition has not yet been determined.—INCO.

The Action of Natural Waters on Lead. G. Miles, *J. Soc. Chem. Ind.*, 67, No. 1, 16-13, (1948) Jan.

The effects of hardness (Langelier Index) and organic matter (oxygen consumed from potassium permanganate) on the initial attack of 67 natural waters on lead are discussed. Although waters containing organic matter are often acidic, it is concluded that organic matter itself, apart from the acidity, can cause increased corrosion of lead. Suitable water treatments are described.—BNF.

DDT in Underwater Protection. *Paint Notes*, 2, No. 8, 278, (1947).

Some unpainted spruce panels treated with a 5% solution of DDT in mineral spirit and immersed in the sea with untreated controls. DDT prevented attack by borers and barnacles.—RPI.

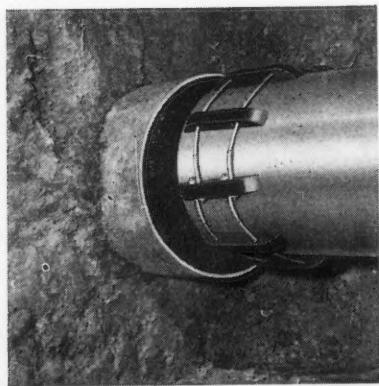
Wrought Iron Ladders. *Corros. & Mat. Prot.*, 5, No. 1, 25, (1948) Jan.-Feb.

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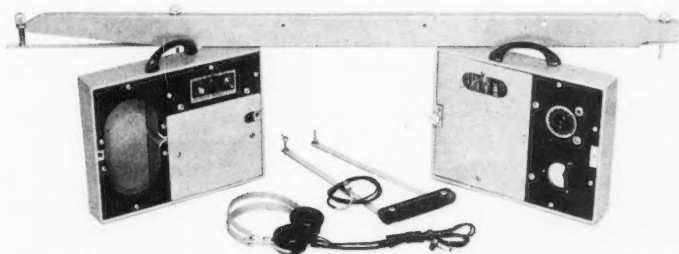
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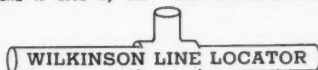


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Index to Advertisers

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Allied Chemical & Dye Corporation Barrett Division	23
Aluminum Company of America (Alcoa)	45
American Brass Co., The (Anaconda)	31
American Hot Dip Galvanizers Association ..	52
American Steel & Wire Co. (U. S. Steel)	25
Associated Research, Incorporated	48
Bechtel Corp. & H. C. Price Co. (Somastic) ..	41
Cathodic Servicing Company	47
Dearborn Chemical Company .. Inside Front Cover	
Dixie Tank & Bridge Company	49
Dow Chemical Company, The (Magnesium Division)	ii
Electro Rust-Proofing Corporation (N. J.)	51
General Paint Hill, Hubbell & Co., Division .. Inside Back Cover	
Haering, D. W. Company, Inc.	43
Jacobs Wind Electric Co., Inc., The	35
Johns-Manville	33
Koppers Company	x, 53
Mavor, James E.	49
Mayes Bros., Inc.	i
Midwestern Engine & Equipment Company, Inc.	vii
Motorola, Inc.	39
National Carbon Company, Inc.	54
Perrault Brothers, Inc. (Glasfloss)	v
Pipe Line Service Corporation	29
Reilly Tar & Chemical Corporation	27
Service Engineers, Inc.	37
Stearns, D. E.	Back Cover
Westinghouse	iv
Wilkinson Products Company	51
Williamson, T. D., Inc.	50

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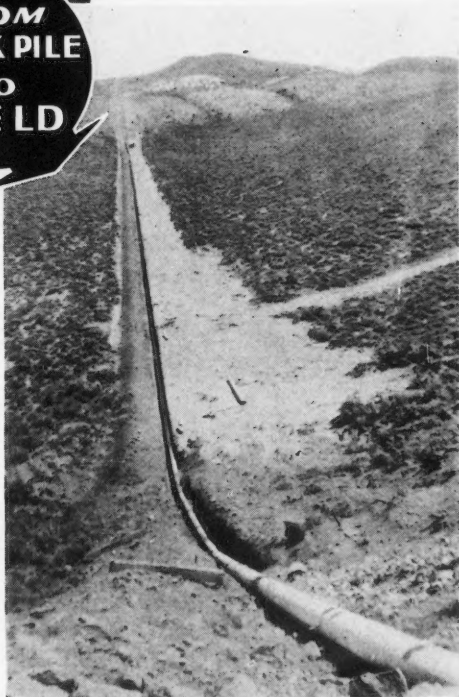
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